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THE
THEORY AND PRACTICE
OF
HYGIENE

THE

THEORY AND PRACTICE

OF

HYGIENE

(NOTTER AND FIRTH)

REVISED AND LARGELY RE-WRITTEN

BY

R. H. FIRTH

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THIRD EDITION

LONDON

J. & A. CHURCHILL

7 GREAT MARLBOROUGH STREET

1908

11958

Printed by BALLANTYNE & Co. LIMITED
Tavistock Street, London

PREFACE

Strictly speaking, this volume is the third edition of a book which Colonel Notter and I brought out in 1896, based upon the well-known work of the late Dr. Edmund A. Parkes. The extent of the changes made in the text is such as to render this edition practically a new work. In making changes, every endeavour has been made to keep the subject-matter well balanced, and not to allow too much stress to be laid upon mere theory at the expense of practical detail. It will be conceded that this object is difficult of attainment, more especially as the theory and practice of hygiene cover a wide range of subjects, many of which involve in their discussion the consideration of technical details.

One of the most notable changes made in the plan of the book has been the omission of bibliographies at the end of individual chapters. These were found to occupy much space, and to be quite out of proportion to their utility. In their place, footnotes have been given wherever it seemed necessary to make a special reference to some authority. The question of Sanitary Law has been a matter of some anxiety. In the former editions this was dealt with in a separate chapter. In this volume, as far as possible, the bearing of special legislation has been discussed at the end of each chapter; thus, the legislation bearing on water-supplies is given at the close of the chapter dealing with the hygiene of water, and that bearing on other matters at the end of their appropriate chapters. This appeared a logical way of dealing with the subject of sanitary law, but is not capable of being carried out in its entirety in a work of this kind, as there are sundry topics which are of interest to the student mainly on account of the legislation to which they have given rise. Instances of this kind are such subjects as nuisances, open spaces, the cleansing of persons, employment of children and the protection of infant life. In order to explain these and similar matters which, while the subject of special sanitary legislation, do not present features of scientific interest, a special chapter has been devoted, under the general heading of Sanitary Administration and Law. As constituting the foundation of all practical sanitary effort, this is made to be the first chapter in this volume. The situation has been further complicated by

the circumstance that after the greater number of the following pages had been put into type, the Legislature passed certain Acts of Parliament which modified in some ways certain previous enactments. To meet this development, a supplementary chapter dealing with "Recent Sanitary Legislation" has been introduced. It is hoped that this will be found sufficiently concise to be read intelligently in conjunction with other sections of the book.

As regards individual chapters, attention may be drawn to those dealing with water, food, habitations, removal and disposal of sewage, disposal of the dead, offensive trades, parasites, the infective diseases, disinfection, vital statistics, and military hygiene, all of which have been modified extensively and in many parts rewritten.

In the section dealing with water analysis every effort has been made to render it practical for the guidance of the sanitary officer. Some stress has been laid upon the need of devoting attention to the microscopical examination of water sediments, and the differentiation or recognition of the grosser microscopic forms to be found in many waters. Formerly, this was a procedure which was never omitted; of late years, since the development of bacteriological methods, it has been neglected, with the result that few students, at the present time, are able to recognise or appreciate the significance of many forms which are demonstrable by a simple microscopical examination. By directing attention to this class of observation, it is hoped that the range of practical instruction in the biological examination of a water sample may be widened. That portion dealing with the bacteriological examination of water has been entirely rewritten and freed from all matter which one's own experience, as a practical worker in this field, has shown to be non-essential to the attainment of an adequate knowledge of the merits or demerits of a given sample of water.

The chapters dealing with foods and beverages have been strengthened by the incorporation of more modern conceptions as to the theory of diets and values of the various food-stuffs. The same idea has dominated the handling of such subjects as habitations, schools, hospitals, drainage, and the disposal of sewage. The chapter dealing with this latter topic has been rewritten, and it is hoped will be found sufficiently clear both as to theory and practice. The chapter on the disposal of the dead is new, and that on the offensive trades has been extended.

The importance which attaches, at the present time, to the part which insects and other living creatures play in the etiology and dissemination of disease has necessitated a ccmplete revision of the chapter on parasites. This has been rewritten and brought, as far as possible, up to date

In the same way, the handling of immunity and the natural history of the infective diseases, as well as that of disinfection, has been entirely on modern lines.

The chapter on vital statistics will be found to be materially changed. At all times this is a difficult subject to discuss in a limited space, but it is hoped that the present effort will not be found to be inadequate. No pains have been spared to place it abreast of the times, and to make the elementary study of biometrics intelligible to the student. In this section, the writer has drawn largely upon the works of Professor Karl Pearson, to whose initiative in this field of work we are mainly indebted for modern developments in the study of vital statistics. It has been found impossible to divest this subject of formulæ, and doubtless to the casual reader some pages may seem unintelligible; but the time has arrived for the student of preventive medicine and other problems intimately associated with the welfare of the race to familiarise himself with methods of inquiry somewhat different from those which have sufficed hitherto. A working knowledge of the higher mathematics must be deemed as essential for the Medical Officer of Health as is a knowledge of bacteriological technique.

The last two chapters in this volume are devoted to a study of the sanitary aspects of life in our naval and land forces. The chapter on marine hygiene has been changed less than that on army sanitation. The latter has been rewritten, and no trouble spared to make it a concise summary of a most important section of preventive medicine. The writer's experiences have been of special value in preparing this chapter, and, in view of the more intimate relation which the inception of a territorial army must develop between the two professions of medicine and of arms, it is hoped that the principles herein enunciated may not be without benefit both to the doctor and the soldier.

Every endeavour has been made to illustrate the text, and the present volume contains over sixty more figures and seven more plates than did the last edition. For many of these drawings the editor has been indebted to brother officers, more especially for some of parasites, fleas and various tropical biting flies. Apart from this general acknowledgment, thanks are especially tendered to Mr. H. Wellcome, to the trustees of the Wellcome Research Laboratories at Khartoum, and to the Director of Education of the Sudan Government for permission to make use of drawings issued by them; to the trustees of the British Museum, and to Mr. E. E. Austen for leave to reproduce various figures; to the Director-General of the Army Medical Service for the loan of blocks from the *Journal of the Royal Army Medical Corps*; also to Dr. J. F. J. Sykes and Mr. Barlow Bennett for permission to

make use of certain of their drawings. To my brother officers, Lieut.-Colonel W. B. Leishman and Captain E. W. W. Cochrane, I am sensibly indebted: to the former for the drawings given in Plate XI. and to the latter for help in reading proof-sheets and for much kindly criticism. The preparation of the various drawings has been facilitated by the artistic skill of Mrs. Allinson-James (Miss Triscott) and by the cordial co-operation of the publishers.

R. H. FIRTH.

FARNBOROUGH, HANTS.

CONTENTS

CHAPTER I

SANITARY LAW AND ADMINISTRATION

	PAGE
Local Sanitary Areas and Authorities	1
Port Sanitary Authorities	6
Medical Officers, Surveyors, and Inspectors of Nuisances	10
Definitions	21
Bye-laws and Regulations	23
Nuisances	27
Parks, Open Spaces and Commons	31
Cleansing of Persons	33
Control of Midwives	35
Employment of Young Persons in Shops	36
Protection of Infant Life	36
Employment of Children	36

CHAPTER II

WATER

Properties of Water	37
On the Quantity and Supply of Water	38
Sources of Water-supply	40
Storage and Delivery	48
Impurities of Water	53
Effects of an Insufficient or Impure Supply of Water	57
Purification of Water	65
Chemical Examination of Water	74
Bacteriological Examination of Water	103
Interpretation of the Results of a Water Analysis	125
Law relating to Water-supply	127

CHAPTER III

AIR

The Composition and Physical Properties of Air	132
Impurities in Air	139
Diseases Produced by Impurities in Air	154
Examination of Air	165

CHAPTER IV

VENTILATION AND HEATING

	PAGE
Quantity of Air required for Ventilation	178
Methods by which the Necessary Quantity of Air can be supplied	183
Methods of Heating and Cooling	204
Examination of the Sufficiency of Ventilation	219

CHAPTER V

FOOD

Classification of the Food-stuffs	223
Nutritive Functions of the Food-stuffs	228
Nutritive Value of the Food-stuffs	233
Quantity of the Food-stuffs required	236
Diseases connected with Food	249
Meat	252
Law relating to Unsound Food and Horse-flesh	266
Fish	268
Eggs	271
Milk	272
Examination of Milk	281
Law relating to the Milk Trade	293
Butter	298
Margarine	302
Cheese	303
Wheat	304
Bread	308
Law relating to Bakehouses	311
Biscuits	312
Barley	313
Rye	314
Oats	316
Rice	316
Maize	317
Millet and Buckwheat	318
Peas and Beans	319
Potatoes	320
Arrowroots, Tapioca, and Sago	321
Sugar	325
Succulent Vegetables and Fruit	326
Concentrated, Prepared, and Preserved Foods	327
Law as to Adulteration of Food	336

CHAPTER VI

BEVERAGES AND CONDIMENTS

Beer	339
Wine	347
Spirits	352
Dietetic Use of Alcohol	355
Tea	360
Coffee	363

PAGE
Paraguay Tea, Kola and Coca 365
Cocoa and Chocolate 366
Lemon- and Lime-juice 367
Vinegar 368
Mustard and Pepper 369
Salt 370

CHAPTER VII

CLOTHING

Materials of Clothing 371
Principles of Selection and Construction of Clothing . . . 376

CHAPTER VIII

EXERCISE

Effect of Exercise 379
Amount of Exercise which should be taken 384

CHAPTER IX

SOIL

Geological Origin of Soils 386
Soil Features which influence Health 390
Comparison of Different Soils 402
Soil in Relation to Special Diseases 404

CHAPTER X

HABITATIONS, SCHOOLS AND HOSPITALS

Sites and Habitations 421
Schools 436
Hospitals 441
Law relating to Streets and Dwellings 454
Common Lodging-houses 460
Tenement Houses 462
Artisans' Dwellings 464
Unhealthy Areas 465
Unhealthy Dwelling-houses 467
Lodging-houses for the Working Classes 470
Cellar Dwellings 472
Canal Boats 474
Movable Dwellings other than Canal Boats 476
Infectious Disease Hospitals 477

CHAPTER XI

SCAVENGING AND CLEANSING

Town and House Refuse 479
Removal of Excreta by Dry Methods 481
Law relating to Scavenging and Cleansing 484

CHAPTER XII

SEWAGE AND SEWAGE DISPOSAL

PAGE
Removal of Sewage by Water Carriage 487
Disposal of Sewage 504
Purification of Sewage 506
Law relating to Removal of Excreta from Houses 520
  Sewerage and Disposal of Sewage 524

CHAPTER XIII

DISPOSAL OF THE DEAD

Law relating to Mortuaries and Burial-grounds 527
Cremation 530

CHAPTER XIV

OFFENSIVE TRADES

Keeping of Animals 532
Slaughtering of Animals 533
Blood and Tripe Boilers 534
Gut-cleaning and Fat-melting 536
Soap-making 537
Fellmongering and Leather-making 538
Glue- and Artificial Manure-making 540
Linoleum- and India-rubber-making 541
Varnish-making and Oil-boiling 542
Paper-making 542
Manufacture of Alkalis 543
Manufacture of Horse-hair 544
Woolsorting 545
Trades associated with the Use of Poisonous Metals 546
Law relating to Trades, Offensive or Otherwise 552
  Alkali and Chemical Works 555
  Slauhter-houses 557
  Factories and Workshops 560

CHAPTER XV

PARASITES

Classification of Parasites 568
Blastomycetes or Yeasts 569
Hyphomycetes or Moulds 569
Protozoa 571
Platyhelminthes 583
Nematodes 592
Acanthocephala 604
Hirudinea 604
Arthropoda 605

CHAPTER XVI

THE INFECTIVE DISEASES

	PAGE
Nature and Origin of the Infective Diseases	630
Immunity and Protection	633
Anthrax	638
Beriberi	643
Cerebro-spinal Fever	645
Chicken-pox	648
Cholera	649
Dengue	653
Diarrhœa	655
Diphtheria	658
Dysentery	665
Enteric Fever	669
Erysipelas	677
Foot and Mouth Disease	678
Glanders	679
Hydrophobia	680
Influenza	683
Kala-azar	685
Leprosy	686
Malaria	687
Malta Fever	690
Measles	693
Mumps	695
Plague	695
Pneumonia	701
Puerperal Pyæmia	703
Relapsing Fever	704
Rötheln	705
Scarlet Fever	706
Sleeping-sickness	710
Smallpox	711
Tetanus	720
Tuberculosis	722
Typhus Fever	728
Whooping Cough	730
Yellow Fever	732
Law relating to Infectious Diseases	735

CHAPTER XVII

DISINFECTION

Heat as a Disinfectant	741
Chemical Disinfectants	749
Standardisation of Disinfectants	765
Disinfection Stations	767
Law relating to Disinfection	768

CHAPTER XVIII

VITAL STATISTICS

Population	770
Marriage-rates	776
Birth-rates	777

	PAGE
Death-rates	780
Infantile Mortality	788
Causes of Death	790
Occupation in Relation to Mortality	796
Life-tables	799
Tests of Longevity	808
Statistical Methods	810
Frequency Curves	812
Correlation	820
Contingency	826
Probability	828

CHAPTER XIX

CLIMATE AND METEOROLOGY

General Effects of Climate	831
Acclimatisation	840
Meteorology	842
Temperature and its Observation	842
Sunshine and Wind	849
Atmospheric Electricity	851
Ozone	852
Atmospheric Humidity	853
Clouds	859
Rainfall	860
Atmospheric Pressure	863
Barometers and Barometric Fluctuations	866

CHAPTER XX

RECENT SANITARY LEGISLATION

Butter and Margarine Act, 1907	876
Education (Administrative Provisions) Act, 1907	877
Public Health Act Amendment Act, 1907	877
Regulations as to Cholera, Plague, and Yellow Fever	880
Notification of Births Act, 1907	882

CHAPTER XXI

MILITARY HYGIENE

Selection of Recruits	883
Barracks	885
Military Hospitals	896
Tents	898
Food of the Soldier	900
Equipment of the Soldier	906
Work of the Soldier	912
Hygiene of the March	913
Hygiene of Camps	917
Military Morbidity and Mortality	933

CHAPTER XXII

MARINE HYGIENE

	PAGE
Nature and Extent of Marine Population	946
Interior Economy of Ships	951
Ventilation of Ships	959
Heating and Lighting of Ships	963
Cleansing and Disinfection of Ships	964
Water-supply of Ships	965
Food on Shipboard	966
Disease, Accident, and Death at Sea	972

APPENDIX

Measures of Length, Weight, and Capacity	975
Table of Factors for Calculating Equivalents of Weight, &c.	976
Chemical Symbols and Atomic Weights	977
Weights of Service Water-pipes	978
Table of Velocities of Discharge from Drains	978
Preparation of Culture Media	978
Table of Log Γ Functions	983
Index	985

DIRECTIONS TO BINDER

Plates I., II., and III.	*to face page*	101
,, IV. and V.	,,	102
Plate VI.	,,	111
,, VII.	,,	448
,, VIII.	,,	450
,, IX.	,,	452
,, X.	,,	574
,, XI.	,,	579
,, XII.	,,	602
,, XIII.	,,	606
,, XIV.	,,	613
,, XV.	,,	621
,, XVI.	,,	624
,, XVII.	,,	626
,, XVIII.	,,	628
,, XIX.	,,	767
,, XX.	,,	862
,, XXI.	,,	864
,, XXII.	,,	930

THEORY AND PRACTICE OF HYGIENE

CHAPTER I

SANITARY ADMINISTRATION AND LAW

In all three main divisions of the British Isles, the Local Government Board is the central authority concerned with the various matters relating to sanitary administration. The Board supervises all the work of local authorities in connection with the various Acts concerned with public health, and in many instances is the court of appeal, interfering when it believes any local authority is neglecting its duty as regards the care of the public health. In *England and Wales*, the powers and duties of the Local Government Board embrace the registration of births, marriages and deaths; public health; local government; drainage; baths and wash-houses; public improvements; artisans' and labourers' dwellings; prevention of disease; vaccination; and local taxation.

In *Ireland*, the duties and powers of the Local Government Board are very similar to those of the English Board. In *Scotland*, the Local Government Board may appoint Medical Officers of Health, Sanitary Inspectors, and is generally empowered to inquire into the sanitary condition of any district and to appoint commissioners to hold such inquiries relating to the public health as it may deem necessary; in fact, the general scope of the powers and duties of the respective English, Irish and Scottish Boards are similar.

The essential and primary element in sanitary administration is the division of the country into sanitary areas, each of which is controlled by a "Sanitary Authority." Before considering the powers and duties of these authorities in connection with public health, it will be more convenient, in the first instance, to explain their nature and areas of authority, and, secondly, to consider what are the statutory provisions with reference to the appointment by them of Medical Officers of Health, Surveyors, and Inspectors of Nuisances, and the general range of the duties of these sanitary officials.

LOCAL SANITARY AREAS AND AUTHORITIES.

In England and Wales.—The whole of England and Wales outside the city of London is divided into (*a*) administrative counties, and (*b*) county boroughs. By the Local Government Act, 1894, the administrative counties are divided into county districts, some of which are urban, and others rural districts. For sanitary administration the county boroughs are deemed to be urban districts, and, with the other urban districts, constitute urban sanitary districts; while the rural districts, each consisting of one or more parishes, are rural sanitary districts.

In every administrative county there is a County Council, who may

appoint one or more Medical Officers of Health for the county, and who have various other powers and duties in connection with the sanitary supervision and administration of the county, more particularly of complaining under section 299, Public Health Act, 1875, in cases where a Sanitary Authority is not doing its duty, and of enforcing the provisions of the Rivers Pollution Prevention Act. They have also considerable powers under the Isolation Hospitals Act, 1892, and as appeal authorities under the Local Government Act, 1894.

In county boroughs the mayor, aldermen, and burgesses, acting by the council, constitute the urban Sanitary Authority. In all other boroughs, the same, acting as the Municipal Council, become, for sanitary purposes, an urban District Council, and as such are an urban Sanitary Authority.

In urban districts, other than county and municipal boroughs, the District Council constitutes the Sanitary Authority; but they may appoint committees, consisting either wholly or partly of their members, for the exercise of sanitary powers; but no such committee will hold office beyond the next annual meeting of the District Council, and the acts of every such committee must be submitted to the council for their approval (Local Government Act, 1894, section 56).

Similarly, in rural districts the District Council is the rural Sanitary Authority. Where the number of councillors of any such district shall be less than five, the Local Government Board may, by Order, nominate such number of persons as are necessary to make up that number from owners or occupiers of property situated in the rural sanitary district. The persons so nominated are entitled to act and vote as members of the rural Sanitary Authority, but not further or otherwise. An alternative procedure is for the Local Government Board to order the affairs of the District to be administered by the District Council of an adjoining district in another county with which it may or may not have been united before the passing of the Local Government Act, 1894 (see section 24). Each rural District Council, as a rural Sanitary Authority, has all the powers, duties, and liabilities that were exercised by the old Boards of Guardians. They have also the same powers for appointing committees as have the District Councils of urban districts other than boroughs (Local Government Act, 1894, section 56).*

The Local Government Act, 1894, created new authorities in the shape of Parish Councils in every rural parish which has a population of 300 or more. Also, by order of the County Council, providing the "Parish Meeting" so resolve, a Parish Council may be established in any rural parish having a population of 100 and upwards, and, with the consent of the Parish Meeting, in any rural parish having a population of less than 100. Also, with the consent of the respective Parish Meetings, neighbouring parishes may be grouped under a common Parish Council, but with a separate Parish Meeting for every parish so grouped. Although, by the Local Government Act, 1894, section 8, some few sanitary powers are possessed by Parish Councils, such as the utilisation of wells, springs, streams within its parish, and power to drain, clean, cover, or remedy the condition of ponds and stagnant pools, also to acquire or hire land for allotments, make official representation to the District Council under the Allotments Act, or to the Medical Officer of Health under the Housing of the Working Classes Act, or to the Local Government Board for granting of urban provisions to their parish or any part of it, these powers in no way derogate from the sanitary obligations of a District Council, which is the true rural Sanitary Authority.

* It is not unlikely that future legislation will abolish rural District Councils and hand over the duties now performed by those bodies to the County Councils.

The Parish Council may complain (section 16) to the County Council if the rural District Council have failed to provide or to maintain sufficient drainage or water-supply for the parish, or to enforce any provision of the Public Health Act, and in that event the County Council may take over to themselves the powers of the District Council for the purpose, or may make an Order for the necessary works to be carried out by the District Council, or by some person appointed by the County Council. Apart from Expenditure under adoptive Acts, a Parish Council must not incur expenses involving more than a *6d.* rate in any year, nor more than a *3d.* rate without the consent of the Parish Meeting. They may raise money on loan, but only with the approval of the Parish Meeting, the County Council, and the Local Government Board.

The Parish Meeting has the exclusive power of adopting certain optional Acts, including the Burial Acts, 1852 to 1885, the Baths and Wash-houses Acts, 1846 to 1882, the Lighting and Watching Act, 1833, and the Public Improvements Act, 1860.

In large rural districts the District Council may appoint parochial committees for outlying parishes to act as a resident subordinate authority, and as its agents in the exercise of the powers delegated to them. If such exist, the members of these committees must be selected from the members of the Parish Council. These parochial committees are completely under the control of the rural Sanitary Authority which made them, and have no jurisdiction beyond the places for which they were respectively formed.

By section 15 of the Local Government Act, 1894, a rural District Council may delegate to a Parish Council any power which it may delegate to a parochial committee under the Public Health Acts, and thereupon those Acts will apply as if the Parish Council were a parochial committee.

The duties which, in the opinion of the Local Government Board, may properly be assigned to a parochial committee are :—(1) Inspection of their district periodically as to need of works of construction, and the presence or abatement of nuisances ; (2) Superintendence of works of repair or construction ; (3) To inquire into and report upon nuisances ; (4) To examine and certify all accounts relating to expenditure within their district ; (5) To report to the rural Sanitary Authority on all matters requiring attention, and upon the manner in which their officers and servants have discharged their duties.

Although the powers conferred on urban and rural Sanitary Authorities are in many respects identical, they are not invariably so. By section 276 of the Public Health Act, 1875, the Local Government Board may, on application of a rural Sanitary Authority, or of persons rated to the relief of the poor, whose assessments amount to one-tenth of the nett rateable value of the district, declare, by order, any provision of that Act in force in an urban sanitary district to be in force in such rural sanitary district, or part thereof. In like manner, the Private Street Works Act, 1892, and the Public Health Acts Amendment Act, 1890, may be put in force in the whole or part of any rural sanitary district. In amplification of the foregoing, by section 25 (7) of the Local Government Act, 1894, similar powers may be exercised by the Local Government Board on application of a County Council or with respect to any parish or part thereof on application of the Parish Council. Experience has shown that the provisions of the Public Health Act hitherto most frequently put in force are, sections 42, 44, 157, and 158, relating to cleansing and watering of streets, and making of bye-laws as to nuisances and new buildings. Other sections which are occasionally put in force are

112 and 114, relating to offensive trades, and 169, 170, which regulate the sanitation of slaughter-houses.

In order to simplify sanitary administration the Local Government Act, 1894, section 36, authorises the Local Government Board to make such orders as will cause—

(1) The whole of each parish, and, unless the County Council for special reasons otherwise direct, the whole of each rural district, to be within the same administrative county.

(2) The whole of each parish, unless the County Council for special reasons otherwise direct, to be within the same county district.

(3) Every rural district which has less than five elected councillors, unless the County Council for special reasons otherwise direct, to be united to some neighbouring district or districts.

The constitution of new boroughs can only be made by the grant of a charter by the Crown, on the advice of the Privy Council; notice of application, however, must be sent to the County Council and the Local Government Board (Local Government Act, 1888, section 56).

In London.—While the Public Health Act, 1875, and the Acts passed from time to time amending it, form the basis of the greater part of the sanitary law in the provinces, comparatively few sections of these Acts apply to the metropolis. Among the sections which do apply are sections 108 and 115, relating to the abatement of nuisances; sections 130, 134, 135, and 140 (as amended by section 2 of Public Health Act, 1889), relating to powers of the Local Government Board with respect to cholera and other infectious diseases; also sections 182 to 186, relating to bye-laws; and section 336, defining the relations of new Sanitary Authorities to completed sewage works of the old Metropolitan Board of Works.

In the rest of England and Wales it has been shown that there is practically one Sanitary Authority acting for each district. In London, with the exception of the Port of London which is under the City Corporation, there is no part where there is not more than one public body exercising the functions of a Sanitary Authority. It is impossible in this work to give a full account of the powers and duties exercised by such diverse bodies as the County Council, the Metropolitan Asylums Board, the Corporation of the City, Borough Councils, and the Police Commissioners.

By the Public Health (London) Act, 1891, section 99, the authority, hereafter called the Sanitary Authority, is (*a*) in the city, the Corporation; (*b*) and in the Metropolitan Boroughs, the Borough Councils; (*c*) in the districts in Schedule B. the District Councils; and (*d*) in places in Schedule C. the Guardians, or, if there be none, the overseers for such place, defraying their expenses as if they were poor-rates.

In Scotland.—Every burgh is a separate area for public health purposes. Of the rural or "landward" parts of Scotland, the primary division is the county, which again is divided into parishes, which, as a rule, are much larger than in England. These parishes are in most counties divided into groups, known as County Districts, and each district is a unit for highway and rural public health administration. There are, on the average, about four districts in each divided county, and about eight parishes in each county district. The boundaries of a district may be altered from time to time, but a parish may not be partly in one county district and partly in another. In counties not divided into districts, the public health area of administration is the county, which of course in this connection does not include the burghs comprised within its geographical limits.

By the Public Health (Scotland) Act, 1897, the central public health

authority in Scotland is the Local Government Board (Scotland). In each burgh the provost, magistrates, and town council, acting as "Burgh Commissioners," are the local authority for public health purposes, and as such exercise the powers conferred by the Public Health (Scotland) Acts on a local authority, and by the Burgh Police (Scotland) Act, 1892, on burgh commissioners.

In the landward or rural districts the public health authority, where a county is undivided into districts, is the County Council, acting together with one representative from the Parish Council of each parish in the county. Where a county is divided into districts, the local authority is the District Committee, consisting of the county councillors and of one representative from each Parish Council within the district. In divided counties certain powers are reserved to the County Council, namely, the appointing of a Medical Officer of Health and Sanitary Inspector, also representing matters to the Local Government Board, and making bye-laws, regulations, and levying rates. The County Council, in addition to the District Committee, has power to enforce the provisions of the Rivers Pollution Prevention Act. County Councils and District Committees may appoint sub-committees to exercise their public health functions. In some counties, a sub-committee is appointed for each parish.

By section 39, Public Health (Scotland) Act, 1897, District Committees can constitute special districts in landward areas for scavenging, and for the removal of manure from mews and other premises (section 42). Provision is also made for cleansing offensive ditches lying near to or forming boundaries of districts and apportioning the cost of same, and for the purification by cleansing and whitewashing of houses in a filthy condition. The cost of these services falls upon the special district.

Generally the limits of the Public Health (Scotland) Act, 1897, follow those of the later English Acts, and this Act incorporates the Lands Clauses Act, and certain sections (sections 6, and 70 to 78) of Railway Clauses Consolidation (Scotland) Act,1845.

In Ireland.—The public health administration in Ireland is governed mainly by the provisions of the Public Health Acts of 1878, 1890, and 1896, and the special orders issued by the Local Government Board for Ireland in pursuance of the first of these Statutes. Though many of the urban areas are under the Act of 1878, still a great number are governed by special Acts, particularly the Towns Improvement (Ireland) Act, 1854, and the Towns Improvement Clauses Act, 1847. It would be a great advantage if the various Acts bearing upon public health administration in Ireland were consolidated. In the main, the Irish Act of 1878 is drawn on the lines of the English Act of 1875, but there are some differences in the provisions, as will be seen subsequently.

By the Public Health Act, 1878, the whole of Ireland is divided into (*a*) urban sanitary districts and (*b*) rural sanitary districts, and each district is subject to the jurisdiction of a Sanitary Authority. Urban sanitary districts consist of :—

1. The city of Dublin.
2. Towns corporate (except Dublin).
3. Town of Carrickfergus, which has Municipal Commissioners under the Municipal Corporations Act (Ireland), 1840.

The foregoing are boroughs within the meaning of the Act of 1878, and the boundary of each urban sanitary district is conterminous with the borough boundary.

4. Eight towns under the Lighting of Towns (Ireland) Act of 1828.

5. Towns under the Towns Improvement (Ireland) Act of 1854.
6. Twelve towns under various local Acts.
7. Towns which have been constituted urban sanitary districts by Provisional Orders of the Local Government (Ireland) Board, and confirmed by Parliament.

The rural sanitary districts are those portions of a poor-law union which are not included in an urban sanitary district. There are 159 of these rural sanitary districts in Ireland.

In the various urban sanitary districts, above detailed, the urban Sanitary Authorities are the Corporations of the city of Dublin and of the corporate towns, and the various towns or municipal commissioners of the other townships. These urban Sanitary Authorities have the same power as similar bodies in England to form and appoint committees.

By section 6, Public Health (Ireland) Act, 1878, the guardians of the union as a corporate body are constituted the rural Sanitary Authority. These rural Sanitary Authorities cannot delegate their powers to committees.

By the Public Health (Ireland) Act, 1896, power is given to the Local Government Board to invest a rural Sanitary Authority in Ireland with urban powers. An omission made in the Irish Act of 1878.

The Irish Local Government Board may also, by Provisional Order, separate from a rural district any municipal town or district wholly situated therein, whether the population be more than 6000 or not, and constitute it an urban sanitary district; or include any such town or district in an adjoining urban sanitary district. The Local Government Board may also add any town, constituted an urban sanitary district, to the rural sanitary district in which it lies. No such provisional order may be made except on petition from one or other town or district, nor, in the event of objection, until after due local inquiry. The Provisional Order is of no force unless and until it is confirmed by Parliament.

PORT SANITARY AUTHORITIES.

In England and Wales.—Under section 287, Public Health Act, 1875, the Local Government Board may, by Order, constitute any Sanitary Authority, whose district abuts upon any port in England or Wales, the Sanitary Authority for the whole or any part of such port. The Board may also combine two or more riparian Authorities for the purpose; or may constitute one Port Sanitary Authority for any two or more ports. The Authority may be constituted permanently or temporarily. Of the sixty Port Sanitary Authorities in existence on December 31, 1893, no less than fifty-three were constituted permanently. An Order constituting a Port Sanitary Authority may assign to it any powers, rights, duties, capacities, liabilities, and obligations of an urban Sanitary Authority, so far as applicable to a Port Sanitary Authority, and to vessels, waters, or persons within its jurisdiction (sections 288 and 289).

The powers and duties of a Port Sanitary Authority consist primarily of those conferred by such of the specified portions of the Public Health Act as the particular Order may decide. The powers usually conferred are those under sections 91 to 111 (nuisances), 120 to 133 (infectious diseases and hospitals), 134 to 138 (prevention of epidemic diseases), 141 and 142 (mortuaries), 182 to 186 and 188 (bye-laws), 189 (appointments of Medical Officer of Health and Inspector of Nuisances), 175 to 177 (relating to purchase of land), and the provisions of the same Act relating to contracts,

arbitrations, the conduct of business, audit, and legal proceedings, as well as section 2 of the Public Health (Ships, &c.) Act, 1885, which applies the provisions of the Act of 1875 as to infectious diseases and hospitals to ships, which come for these purposes within the definition of "house." These various powers and duties are further extended by the Cholera Regulations made by the Local Government Board under section 130 of the Public Health Act, 1875, and the Public Health Act, 1896, and by the Order prescribing the duties of a Port Medical Officer of Health (*see* page 13). The regulations now in force under Public Health Act, 1896, and Public Health (Ports) Act, 1896, are as follows :—

Regulations as to Cholera, Yellow Fever, and Plague.—Every Port or other Sanitary Authority, within whose district persons are likely to be landed from ships "coming foreign," must appoint a place for mooring such as are infected, and must provide for the reception of cases (actual or suspected) of cholera, yellow fever, or plague. A ship is to be deemed "infected" if there is or has been during the voyage, or during stay in port of departure, or in a port of call any case of the above-named diseases on board. An infected ship must hoist a black and yellow flag when within three miles of the coast of England and Wales. The Customs Officer, who is the first to board the ship, must, as far as possible, ascertain whether it is "infected" or not, and if he has reason to believe that it is, or that it has come from an infected port, he must obtain from the master (or from the surgeon if there be one) a written statement in prescribed form declaring the occurrence or non-occurrence of cases or suspected cases during the voyage. If he finds the ship to be infected, he must order the master to anchor, and must give notice to the Sanitary Authority of the port at which the ship is about to call.

If from such warning, or from other information, the Medical Officer of Health has any reason to believe that any ship within the jurisdiction of his Sanitary Authority is infected, he must forthwith visit and examine it and *may* do so if it comes from an infected port. If he finds that there is or has been a case (of one of the three diseases in question) on board, he must certify accordingly to the master, who is thereupon bound to moor in the place appointed. The Medical Officer of Health must then examine every person on board, none being allowed to leave the ship until the examination is made.

All who are found to be suffering from such disease are to be removed to the hospital or place provided by the Sanitary Authority, if their condition admit of it, and must not leave such place until the Medical Officer of Health certifies that they are free from disease. If they cannot be removed, the ship remains subject to the control of the Medical Officer of Health, without whose written consent the infected persons cannot leave the ship.

Persons certified by the Medical Officer of Health to be suffering from an illness which he suspects may prove to be one of the three, may be detained either on the ship or in some place provided by the Sanitary Authority for not more than two days, in order that it may be ascertained whether their illness is or is not of the kind suspected. No person, not certified as above, is to be permitted to land unless he satisfies the Medical Officer of Health as to his name, place of destination, and address at such place; and the Medical Officer of Health must give such names and addresses to the clerk of the Sanitary Authority, who must transmit them to the Sanitary Authority of the districts in question. The Medical Officer of Health must give directions and take such steps as may appear to him to be necessary for preventing the spread of infection, and the master of the

ship must carry out such directions as are given to him. In the event of a case ending fatally on board, the master must, at the direction of the Sanitary Authority, either bury the body at sea, properly weighted, or deliver it to the Sanitary Authority for interment. He must disinfect and, if necessary, destroy the clothing, bedding, and other articles of personal use likely to retain infection, which have been used by infected persons ; and disinfect the ship and disinfect or destroy all articles therein probably infected, according to the directions of the Medical Officer of Health. If he believes the ship to be infected, or to come from an infected port, the Medical Officer of Health may order the bilge water and water ballast to be pumped out before the ship enters dock, or may cause the water-ballast tanks to be sealed, if emptying them would endanger the ship. He may order all casks or tanks containing drinking water to be emptied and cleansed on the Sanitary Authority providing a proper supply.

When a vessel is not infected, but has passengers on board who are in a filthy or otherwise unwholesome condition, the Medical Officer of Health may certify to the master, that in his opinion it is desirable, with a view to checking the introduction or spread of cholera, yellow fever, or plague, that no persons should be allowed to land until they have satisfied him as to their names and places of destination, and addresses at such places. Thereupon the same measures are to be adopted as in case of persons permitted to leave an infected ship.

In addition to the foregoing regulations, Orders are from time to time issued, and afterwards rescinded, by the Local Government Board, prohibiting the importation of rags, &c., from infected foreign ports, or requiring that they shall be disinfected or destroyed, to the satisfaction of the Medical Officer of Health. The regulations in this connection, now in force, are contained in Orders dated August 5 and September 13, 1893 ; they provide that " no dirty bedding, or disused or filthy clothing, whether belonging to emigrants or otherwise, from France or from any foreign port in Europe north of Dunkirk, other than ports of Sweden, Norway, and Denmark, or from any port on the Black Sea or Sea of Azov, whether in Russia, Roumania, Bulgaria, or Turkey, or from any other port of Turkey in Asia should be delivered overside, or landed except for the purpose of disinfection or destruction." Disinfection must be carried out at the cost of the owner, and to the satisfaction of the Medical Officer of Health, by steam under pressure at a temperature not less than 212° F. In default of such disinfection within forty-eight hours, the articles are to be destroyed. The terms " bedding " and " clothing " include all such articles when torn up, but do not include " rags compressed by hydraulic force transported as wholesale merchandise in bales surrounded by iron bands, and with marks and numbers showing their origin, and accepted as such by the Commissioners of His Majesty's Customs."

In virtue of the powers granted by section 134, Public Health Act, 1875, the Local Government Board have issued certain general directions for dealing with rats on ships, particularly when coming from plague-infected ports. The directions are as follows :—

(1) On the arrival in port of a vessel whereon during the voyage plague or sickness suspected to be plague has occurred, measures should be taken to secure the destruction of the rats on board the vessel. Until this has been done, endeavours should be made to prevent rats leaving the ship, by mooring the vessel a sufficient distance from other ships and from the shore, and by placing guards on cables and hawsers in use for mooring purposes.

(2) In the case of vessels that have come from places infected with plague, but on board of which no plague or suspected plague has occurred, strict inquiries should be made on their arrival in port as to mortality or sickness among rats during the voyage. Should this have

occurred, the Authority would do well to obtain the body of a sick rat for the purpose of ascertaining the nature of the malady affecting those animals on board the vessel. In the event of the malady being found to be plague, the ship should be dealt with as under paragraph (1).

(3) Exceptional sickness or mortality among rats on board any vessel within the district, whatever may have been her port of departure, should be viewed with suspicion and as giving occasion for action similar to that indicated under paragraph (2).

(4) Rats when destroyed on ship-board should not be handled ; they should be cremated at once.

(5) In the event of rats on board any ship being found to be infected with plague, all parts of the vessel frequented by those animals should, as far as possible, be disinfected.

(6) The authorities of seaport towns invaded by plague should endeavour to secure the destruction of the rats of the town, not least those inhabiting the docks and quay-side warehouses. Measures should be taken to guard against shore rats making their way on board vessels lying in the port, and attempts made to destroy all rats on board ships about to proceed on their voyage. Captains of such vessels should be urged to take steps during the ensuing voyage for the destruction of rats that may have remained alive on board their vessels notwithstanding the action of the Local Authority.

The Corporation of London are the Port Sanitary Authority of the Port of London, by the Public Health Act, 1872, and since confirmed by section 111 of the Public Health Act (London), 1891. The duties, powers, and obligations of the Sanitary Authority of the Port of London are the same as those of all other Port Sanitary Authorities in England and Wales.

In Scotland.—The Public Health Act, 1896, repeals the old Quarantine Act of 1825 and extends the powers of the Local Government Board to issue Orders under sections 130 and 134 of the Act for 1875, dealing with epidemic, endemic, or infectious diseases.

The Public Health (Ports) Act, 1896, enables the Local Government Board to issue orders making all or any of the provisions of the Infectious Diseases Prevention Act, 1890, applicable to any Port Sanitary Authority.

Under section 172, Public Health (Scotland) Act, 1897, the Local Government Board for Scotland may by Order constitute any Local Authority of a district forming part of a port the "Port Local Authority," and this authority may, with the sanction of the Local Government Board, delegate to any Local Authority within or bordering on their district, the exercise of any powers conferred on such authority by Order of the Board (section 174). The regulations issued by the Board for the prevention of epidemic disease will be enforced by the Port Local Authority (section 78). The Local Government Board (under section 79) have issued directions for the destruction of rats on ship-board, practically the same as given above by the English Board.

In Ireland there are no Port Sanitary Authorities such as exist in England and Wales. The Irish Local Government Board have similar powers to make regulations in respect of sea-borne cholera or other infectious disease, by section 148 of the Public Health (Ireland) Act, 1878, as have the English Board under the English Acts ; and the provisions of the Public Health Act, 1889, apply equally to Ireland as to England. The regulations now in force in Ireland under these enactments are contained in the Orders of the Local Government Board for Ireland, dated December 6, 1890 (as amended on July 26, 1892), and September 10, 1892. These regulations are practically the same as those of the English Board. With reference to the importation of rags from places in which cholera has been prevalent, the Irish Local Government Board issued Orders on August 15, 1893, and September 18, 1893, which, in all essential particulars, correspond to the analogous Orders of the English Board.

MEDICAL OFFICERS, SURVEYORS, AND INSPECTORS OF NUISANCES.

In England and Wales.—Section 189 of the Public Health Act, 1875, requires every urban Sanitary Authority to appoint one of each of these officers, and provides that the officers so appointed are to be fit and proper persons. A rural Sanitary Authority is not required to appoint a Surveyor, but by section 190 of the same Act must, from time to time, appoint fit and proper persons to be Medical Officers of Health and Inspector of Nuisances; the latter may also be the Surveyor. No special power has yet been given to County Councils to appoint county Inspectors of Nuisances, although such a course has been adopted in some cases. Two or more Sanitary Authorities may appoint the same Medical Officer of Health or the same Inspector of Nuisances; and, apart from this, the Local Government Board is empowered (section 286) compulsorily to unite districts for the purpose of appointing these sanitary officials to act in such special united districts. County Councils are authorised, by section 17, Local Government Act, 1888, to appoint county Medical Officers of Health, who are forbidden to hold other appointments or engage in private practice without the written consent of the council. Under this same section Sanitary Authorities have power to avail themselves of the services of these county Medical Officers on such terms as to contribution to his salary as may be agreed with the County Council. So long as such an arrangement is in force, the obligation of the Sanitary Authority under the Act of 1875 to appoint a Medical Officer of Health is to be deemed to be satisfied without the appointment of a separate Medical Officer.

If any part of the salary of the Medical Officer of Health is repaid to a local authority, the Local Government Board has the same powers in regard to qualification, appointment, duties, salary, and tenure of office as it has in the case of a Poor-Law Medical Officer (Public Health Act, 1875, section 191).

Qualifications of Medical Officer.—Section 18 of the Local Government Act, 1888, requires (except when the Local Government Board, for reasons brought to their notice, may see fit in particular cases especially to allow) every Medical Officer of Health appointed after the passing of the Act to be legally qualified in medicine, surgery, and midwifery; and further, if appointed after the 1st of January 1892 to a district having at the last census 50,000 inhabitants or more, to be the registered holder of a diploma in Public Health under section 21 of the Medical Act, 1886; or have been, during some three consecutive years prior to 1892, a Medical Officer of a district with a population, at the last census, of not less than 20,000; or have been for not less than three years a Medical Officer or Inspector of the Local Government Board.

Tenure of Office by Medical Officer.—Unless a portion of the salary is repaid to the Sanitary Authority out of imperial revenue, transferred to the county and borough councils by the Local Government Act, 1888, the Local Government Board have no control over the tenure of office. If, however, a refund is made, the Medical Officer of Health may continue to hold office for such period as the Sanitary Authority may, with the approval of the Local Government Board, determine, or until he die, resign, or be removed by such authority with the consent of the Local Government Board or by that Board. The Sanitary Authority may suspend him, but must forthwith report their action, together with the cause, to the Local

Government Board, the latter Board having power to remove the suspension. In the event of disagreement as to either salary or duties, a Sanitary Authority have power to give six months' notice to determine the appointment, but only with the consent of the Local Government Board. Where no part of a Medical Officer's salary is repayable, none of these approvals is necessary; the authority may fix his salary at as low a sum as they please; and if he is appointed by an urban Sanitary Authority, section 189 of the Public Health Act, 1875, permits of his removal from office at their pleasure.

In a recent case, where there was a difference of opinion between the Local Government Board and a Rural District Council as to the appointment of its Medical Officer of Health, the central Board took action under section 286 of the Public Health Act, 1875, and formed compulsorily a joint district which embraced the recalcitrant authority. This is an unsatisfactory situation, and also dilatory, as it involved the issue of a Provisional Order which was without force until confirmed by Parliament. The Local Government Board should be empowered not only to act on its own initiative in these matters, but also to unite districts when necessary, without confirmation by Parliament. It is also desirable that all combinations of Sanitary Authorities or districts should have about them a compulsory element.

Duties of the Medical Officer.—The duties of a Medical Officer of Health are the same whether a contribution is made to his salary or not by the Local Government Board, except that in the latter case he must report his appointment to the Board within seven days. "A copy of the annual report and of every special report must be sent to the Local Government Board, whether there is any repayment of salary or not; but there is no compulsion in this respect as regards Medical Officers of Health appointed prior to March 1880, if no repayment of salary is claimed by the authority. County Councils are entitled to receive copies of all annual and other reports which the Medical Officer of any district within the county is required to send to the Local Government Board; and in default may refuse to pay any contribution to his salary which otherwise they would be liable to pay."

The regulations of the Local Government Board, issued March 23, 1891, and still in force, provide that the following shall be the duties of a Medical Officer of Health in respect of the district for which he is appointed, viz.:—

(1) He shall inform himself as far as practicable respecting all influences affecting, or threatening to affect, injuriously, the public health within the district.

(2) He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

(3) He shall, by inspection of the district, both systematically at certain periods and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

(4) He shall be prepared to advise the Sanitary Authority on all matters affecting the health of the district, and on all sanitary points involved in the action of the Sanitary Authority; and in cases requiring it he shall certify for the guidance of the Sanitary Authority or of the Justices as to any matter in respect of which the certificate of a Medical Officer of Health or a medical practitioner is required as the basis or in aid of sanitary action.

(5) He shall advise the Sanitary Authority on any question relating to health involved in the framing and subsequent working of such bye laws and regulations as they may have power to make, and as to the adoption by the Sanitary Authority of the Infectious Disease (Prevention) Act, 1890, or of any section or sections of such Act.

(6) On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit without delay the spot where the outbreak has occurred, and inquire into the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and take such measures for the prevention of disease as he is legally authorised to take under any Statute in force in the district, or by any resolution of the Sanitary Authority.

(7) Subject to the instructions of the Sanitary Authority, he shall direct or superintend the work of the Inspector of Nuisances in the way and to the extent that the Sanitary Authority shall approve, and on receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps as he is legally authorised to take under any Statute in force in the district, or by any resolution of the Sanitary Authority, as the circumstances of the case may justify and require.

(8) In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the Sanitary Authority, he shall himself inspect and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour or milk, and any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, exposed for sale, or deposited for the purpose of sale or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be dealt with by a Justice according to the provisions of the Statutes applicable to the case.

(9) He shall perform all the duties imposed upon him by any bye-laws and regulations of the Sanitary Authority, duly confirmed where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorised to frame bye-laws and regulations.

(10) He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

(11) He shall attend at the office of the Sanitary Authority or at some other appointed place, at such stated times as they may direct.

(12) He shall from time to time report in writing to the Sanitary Authority his proceedings, and the measures which may require to be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been enabled to ascertain the same.

(13) He shall keep a book or books, to be provided by the Sanitary Authority, in which he shall make an entry of his visits, and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon and of any action taken on previous reports; and shall produce such book or books, whenever required, to the Sanitary Authority.

(14) He shall also prepare an annual report, to be made to the end of December in each year, comprising a summary of the action taken during the year for preventing the spread of disease, and an account of the sanitary state of his district generally at the end of the year. The report shall also contain an account of the inquiries which he has made as to conditions injurious to health existing in his district, and of the proceedings in which he has taken part or advised under the Public Health Act, 1875, so far as such proceedings relate to those conditions; and also an account of the supervision exercised by him, or on his advice, for sanitary purposes, over places and houses that the Sanitary Authority have power to regulate, with the nature and results of any proceedings which may have been so required and taken in respect of the same during the year. It shall also record the action taken by him, or on his advice, during the year, in regard to offensive trades, and to factories and workshops. The report shall also contain tabular statements (on forms to be supplied by the Local Government Board, or to the like effect) of the sickness and mortality within the district, classified according to diseases, ages, and localities.

(15) He shall give immediate information to the Local Government Board of any outbreak of dangerous epidemic disease within the district, and shall transmit to the Board a copy of each annual and of any special report. He shall make a special report to the Local Government Board as to any advice he may give to his Sanitary Authority as to the closure of any school or schools.

(16) When giving information to the Local Government Board of the outbreak of infectious disease, or transmitting to them a copy of his annual or any special report, he must give the like information, or transmit a copy of such report, to the County Council of the county in which his district is situated.

(17) In matters not specifically provided for in this Order he shall observe and execute the instructions of the Local Government Board on the duties of Medical Officers of Health and all the lawful orders and directions of the Sanitary Authority applicable to his office.

(18) Whenever the Local Government Board shall make regulations for all or any of the purposes specified in section 134 of the Public Health Act, 1875, relating to the Prevention of Infectious Diseases, and shall declare the regulations so made to be in force within any area comprising the whole or any part of the district, he shall observe such regulations so far as the same relate to or concern his office.

The duties of the Medical Officer of Health to a *Port Sanitary Authority* are defined by the Local Government Board in terms which are very similar to those given above, omitting the references to regulated trades and inspec-

tion of food, and substituting " ships " for " houses," and " shipping within the district " for " district."

" He shall inform himself as far as practicable respecting all conditions affecting or threatening to affect injuriously the health of crews and other persons on ship-board within the district. . . . He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases in the ships and other vessels within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation. . . . He shall, by inspection of the shipping in the district, keep himself informed of the condition injurious to health existing therein. . . . On receiving information of the arrival within the district of any ship having any infectious or epidemic disease of a dangerous character on board, or of the outbreak of any such disease on board any ship within the district, he shall visit the vessel without delay, and inquire into the causes and circumstances of such outbreak, and advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and so far as he may be lawfully authorised to assist in the execution of the same. . . . On receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance, injurious to health, or of any overcrowding in a ship, he shall, as early as practicable, take such steps authorised by the Public Health Act, 1875, on that behalf as the circumstances of the case may justify and require . . . also, when any vessel within his district has had dangerous infectious disease on board, he shall give notice thereof to the Medical Officer of Health of any port in the United Kingdom whither such vessel is about to sail."

Annual Reports by Medical Officer.—Regarding these, the following instructions have been issued by the Local Government Board :—

Every Medical Officer of Health, appointed under Order of the Local Government Board, is required to make an annual report with regard to each sanitary district, or division of a district, which is under his superintendence. This report is to be for the year ending December 31, or if the officer at that date has not been in office for a whole year, then for so much of the year as has elapsed since his appointment. The report is to be made to the council by whom he is appointed, and the Medical Officer of Health himself should send a copy of it to the Local Government Board and to the County Council or County Councils of the county or counties within which his district may be situated. It should be made as soon as practicable after the expiration of the year to which it relates. The Medical Officer of Health ought not, in general, to have any difficulty in doing this within a month or six weeks ; but if from any special circumstances the report cannot be completed within six weeks, it should be understood that the delay must not be indefinite, and that the report should be in the hands of his Council, and of the Board, within, at most, three months from the end of the year. Any special circumstance preventing the delivery of the Board's copy within two months from the end of the year should at once be reported to the Board. The Board's copy of the report should be forwarded to them when the original is sent to the Council, except where the report is likely to be printed by order of the Council. In such cases the Board need only be supplied with a printed copy. It is very desirable that the annual report should be printed, for the sake of facility of reference and in order that a supply of copies may be available for distribution among the Town or District Councillors and other persons interested.

Article 18 (section 14) of the Board's Order of March 1891, respecting the duties of the Medical Officer, specifies the information to be contained in the annual report. It should be concerned chiefly with the conditions affecting health in the district and with the means for improving those conditions. It should contain an account, brought up to date, of the sanitary circumstances of the district, and of any improvements or deterioration in these circumstances which may have occurred during the year. Care should be taken to report fully on the influences affecting or threatening to affect injuriously the public health in the district, and on the action which has been taken or which may be needed, with a view to combat these influences. It is of especial importance that the Medical Officer of Health should record what action has been taken to remedy unhealthy conditions which have been reported by him in previous reports, and that attention should be called, year by year, to such as remain unremedied.

As subjects concerning which the Board desire to obtain, through annual reports of Medical Officers of Health, not only definite general information, but record also of particular changes of condition that may have occurred incidentally or by action of the local authority, the following deserve to be especially borne in mind :—

Physical features and general character of the district. House accommodation, especially for the working classes ; its adequacy and fitness for habitation. Sufficiency of open space about houses, and cleanliness of surroundings. Supervision over erection of new houses. Sewerage and drainage ; its sufficiency in all parts of the district. Condition of sewers and house drains. Method or methods of disposal of sewage. Localities where improvements are needed. Excrement disposal ; system in vogue ; defects, if any. Removal and disposal of house refuse—whether by public scavengers or by occupiers ; frequency and method. Water-supply of the district or its several parts ; its source (from public service or otherwise),

nature (river-water, well-water, upland water, &c.), sufficiency, wholesomeness, and freedom (by special treatment or otherwise) from risks of pollution. Places over which the Council have supervision, *e.g.*, lodging-houses, slaughter-houses, dairies, cowsheds and milkshops, bakehouses, factories and workshops, and offensive trades. To these may be added such matters as common lodging-houses, tenement-houses, back-to-back houses; house drainage and connections; industries of the district; river pollution by sewage and trade effluents; burial-grounds; adoptive Acts, bye-laws and regulations in force; action taken under the above, and under the Sale of Food and Drugs Acts; the Housing of the Working Classes Acts; Canal Boats Act; meteorological data; prevalence of epizootic or epiphytic disease; vaccination (latest available returns); legal proceedings.

Other information should relate to nuisances; proceedings for their abatement, any remaining unabated. Methods of dealing with infectious diseases; notification; isolation; hospital accommodation and its sufficiency; disinfection.

With regard to such points it should be remembered that these reports are for the information of the Board and of the County Council as well of the Council of the District, and that a statement of the local circumstances and a history of local sanitary questions, which may seem superfluous for the latter, may often be needed by the former bodies.

Section 132 of the Factory and Workshop Act, 1901, requires that "the Medical Officer of Health of every District Council shall, in his annual report to them, report specifically on the administration of this Act in workshops and workplaces, and he shall send a copy of his annual report, or so much of it as deals with this subject, to the Secretary of State." The copy should be addressed to the Secretary of State, Home Office, Whitehall, and the foregoing remarks with respect to the transmission of the report to the Local Government Board apply also to its transmission to the Home Office. The Medical Officer is required to report on the administration of the Factory and Workshop Act, 1901, only in so far as this administration is in the hands of the District Council and is concerned with matters in his department. In reporting on the sanitary administration of workshops and workplaces, he should include an account of the action with respect to factories, workshops, and workplaces taken under the Public Health Acts, as well as under the Factory and Workshop Act. In this report, the Medical Officer should state what action has been taken to remedy any defective conditions met with under each heading. He should state whether section 22 of the Public Health Act (Amend.), 1890, is in force in the district, and what standard of "sufficiency and suitability" of sanitary accommodation is adopted locally. As regards bakehouses, section 101 of the Factory and Workshop Act, 1901, forbids the use after January 1, 1904, of any underground bakehouse, *i.e.*, any room used for baking or for any process incidental thereto, so situate that the surface of the floor is more than three feet below the surface of the footway of the adjoining street, or of the ground adjoining the room, unless in the case of an underground bakehouse so used at the passing of the Act the District Council are satisfied that it is suitable for the purpose as regards construction, light, ventilation, and in all other respects, and have given a certificate of its suitability. It is desirable that the Medical Officer should record how many such certificates of suitability have been given by the District Council, and what were the conditions required to be complied with in the granting of such certificates.

A Medical Officer of Health, in reporting his proceedings and advice, should put on record whether he has made systematic inspections of his district. By "systematic inspections" are meant inspections independent of such inquiries as the Medical Officer may have to make into particular outbreaks of disease, or into unwholesome conditions to which his attention has been especially called by complaints or otherwise: and such inspections will include the house-to-house inspections which may be necessary in particular localities. In making systematic inspections, as in much of his other action, the Medical Officer will usually have required the assistance of the Inspector of Nuisances: and the Medical Officer should include in his report an account of the action which, at his instance, the inspector may have taken for the removal of nuisances injurious to health.

The report should deal with the extent, distribution, and causes of disease, especially of epidemic and notifiable diseases, within the district; and should give an account of any noteworthy outbreaks of such diseases during the year under review, stating the result of his investigations into their origin and propagation, and the steps taken by him, or on his advice, with a view to check their spread.

The tabular statements of sickness and mortality in the district during the year, to be made on the forms supplied for the purpose, should be the subject of comment in the text of the report, in so far as deductions from them may assist the Board and the Councils concerned to an appreciation of the lines of action needful in the future.

In preparing his annual report, on the lines indicated above, the Medical Officer of Health will naturally have to make use of various sources of information; the more important of these are the following:—(*a*) Returns of registered deaths, obtained weekly from each of the registration subdistricts within the area, (*b*) notification returns of certain infectious diseases, (*c*) returns of pauper sickness furnished by all district and workhouse medical officers appointed after February 28, 1879; also similar returns given

by Medical Officers of district schools appointed after June 24, 1879. The Medical Officer will avail himself of the periodical reports of the Registrar-General and of the various inspectors of the Local Government Board. He will also make himself familiar with the map of his district, and with any local Acts of Parliament in force, together with the chief Statutes dealing with public health, or any other Acts which the special circumstances of his district may render important. In connection with this part of his duties, every Medical Officer of Health will find such works as Lumley's or Glen's Public Health Act, Glen's Local Government Board Sanitary Orders and the Model Bye-laws of the Local Government Board as most valuable for reference. He should be in possession also of all the information regarding his district given by the census reports. It is desirable to keep registers for each village, hamlet or part of a district, the dates and particulars of every death and of all notified cases of infectious disease. In urban areas, this is best arranged as a street register. Registers of all deaths occurring in certain trades will facilitate greatly any future investigation which the Medical Officer may have to make into the influence of those trades upon mortality. At first sight it may appear that the records to be kept by a Medical Officer of Health are formidable, but if the work of his office is systematically carried out and well arranged, the labour involved is much less than might be expected.

For the Medical Officer of Health, a systematic and simple method of keeping his statistical facts is of the first importance. This is particularly so in regard to the tabulation of the causes of death. He may append to his annual report a table of the deaths at all ages and from all causes on the model of the Registrar-General or of those as required by the Local Government Board. But for practical purposes connected with public health, and for weekly or monthly issue, a simpler form is often preferable. Individual ingenuity will readily be able to draw up a suitable table, which should be divided into a few well-marked age-periods, as infancy, early and late childhood, adolescence, early and late adult life, and old age, each of which has its several dangers to health, and social or industrial conditions. These periods would be, under 1 year, 1 to 5, 5 to 10, 10 to 20, 20 to 40, 40 to 70, and over 70.

Care should be taken to give all the zymotic diseases, phthisis and the preventable diseases generally in detail; under diphtheria may be grouped croup and any fatal cases of so-called putrid sore throat, but in the present day, with increased facilities for bacteriological observation, the errors in diagnosis of these cases should be reduced to a minimum; in any case where doubt exists, a short explanatory note in the column of remarks should be given. So also "cholera" when reported in the absence of an epidemic, "cholera infantum," and the so-called "dysentery," except in the case of persons returning invalided from the tropics, are best grouped together under the heading of "diarrhœa and enteritis." Where possible tubercular phthisis should be distinguished from the non-tubercular, but in most cases phthisis will be found most conveniently noted as a single item, while "all other respiratory diseases" may constitute a second heading. Scrofula may be included under the general term of phthisis and tuberculosis. Syphilis should, when possible, be separately noted and efforts made to trace and clear up ambiguous cases where there is reason to suspect that this disease is the original cause of death. This is especially important in regard to the congenital form, as the reported mortality from it does not represent the truth, many cases being returned as "marasmus," "tabes," &c.

Diseases of the heart, kidneys, and liver, except cancer, may be bracketed in a comprehensive class of "diseases of the internal organs" with the omission of separate headings for so-called "dropsy" and "jaundice," these latter really being only symptoms and without importance to questions of public health. Cancers of all kinds and parts should form a single and separate group, so also should puerperal pyæmia. Diseases of the nervous system must form a distinct heading, but it is advisable to exclude "teething" and "convulsions" from it, unless it is clear that they are not the pathological expression of gastro-intestinal derangement, the result of improper feeding. These causes of death constitute a serious source of error in infantile mortality returns, but a tactful Medical Officer of Health can often, by judicious inquiry, obtain sufficient information to correct such returns, so as practically to allocate them to their proper position under the heading of "improper or defective feeding of infants."

Some excellent statistical forms for public health purposes have been suggested and drawn up by the Society of Medical Officers of Health. The forms given on pages 17 and 18, are the statistical tables required by the Local Government Board to be appended to the annual reports of Medical Officers of Health.

The Duties of a Sanitary Inspector.—In the Public Health Act, 1875, this officer is always spoken of as the Inspector of Nuisances, and he must be appointed formally under that title; the Act of 1875 does not recognise the title Sanitary Inspector, whereas, as will be seen subsequently, the Public Health (London) Act, 1891, does so. Practically, the two titles are indifferently employed to indicate one and the same official. His duties are closely connected with those of a Medical Officer of Health, but the broad line separating them will be apparent from the following definition of his duties formulated by the Local Government Board :—

(1) He shall perform, either under the special directions of the Sanitary Authority, or (so far as authorised by the Sanitary Authority) under the directions of the Medical Officer of Health, or in cases where no such directions are required, without such directions, all the duties specially imposed upon an Inspector of Nuisances by the Public Health Act, 1875, or by any other Statute or Statutes, or by the Orders of the Local Government Board, so far as the same apply to his office.

(2) He shall attend all meetings of the Sanitary Authority when so required.

(3) He shall by inspection of the district, both systematically at certain periods and at intervals as occasion may require, keep himself informed in respect of the nuisances existing therein that require abatement.

(4) On receiving notice of the existence of any nuisance within the district or of the breach of any bye-laws or regulations made by the Sanitary Authority for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of bye-laws or regulations.

(5) He shall report to the Sanitary Authority any noxious or offensive businesses, trades, or manufactories established within the district, and the breach or non-observance of any bye-laws or regulations made in respect of the same.

(6) He shall report to the Sanitary Authority any damage done to any works of water supply, or other works belonging to them, and also any case of wilful or negligent waste of water supplied by them, or any fouling, by gas, filth, or otherwise, of water used for domestic purposes.

(7) He shall from time to time, and forthwith upon complaint, visit and inspect the shops and places kept or used for the preparation or sale of butchers' meat, poultry, fish, fruit, vegetables, corn, bread, flour, milk, or any other article to which the provisions of the Public Health Act, 1875, in this behalf shall apply, and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, milk, or other article as aforesaid which may be therein; and in case any such article appear to him to be intended for the food of man, and to be unfit for such food, he shall cause the same to be seized, and take such other proceedings as may be necessary in order to have the same dealt with by a Justice: Provided, that in any case of doubt arising under this clause, he shall report the matter to the Medical Officer of Health, with the view of obtaining his advice thereon.

(8) He shall, when and as directed by the Sanitary Authority, procure and submit samples of food, drink, or drugs suspected to be adulterated, to be analysed by the analyst appointed under "The Sale of Foods and Drugs Act, 1875," and upon receiving a certificate stating that

STATISTICAL TABLES (A) AND (B) REQUIRED BY THE LOCAL GOVERNMENT BOARD TO BE APPENDED TO THE ANNUAL REPORTS OF MEDICAL OFFICERS OF HEALTH.

(A).—TABLE OF DEATHS *during the year* 19 , *in the* *Sanitary District of* ; *classified according to* DISEASES, AGES, *and* LOCALITIES.

Names of Localities adopted for the purpose of these Statistics; public institutions being shown as separate localities. *See Note* 4. (a)	Mortality from all Causes, at subjoined Ages. At all ages. (b)	Under 1 year. (c)	1 and under 5. (d)	5 and under 15. (e)	15 and under 25. (f)	25 and under 65. (g)	65 and upwards. (h)	(i)	Mortality from subjoined Causes, distinguishing Deaths of Children under Five Years of Age. 1 Small-pox.	2 Scarlatina.	3 Diphtheria.	4 Membranous Croup.	5 Fevers. Typhus.	6 Fevers. Enteric or Typhoid.	7 Fevers. Continued.	8 Fevers. Relapsing.	9 Fevers. Puerperal.	10 Cholera.	11 Erysipelas.	12 Measles.	13 Whooping Cough.	14 Diarrhœa and Dysentery.	15 Rheumatic Fever.	16 Ague.	17 Phthisis.	18 Bronchitis. Pneumonia. Pleurisy.	19 Heart Disease.	20 Injuries.	21 All other Diseases.	22 Total.
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The subjoined Numbers have also to be taken into account in judging of the Mortality of this Division of the Sanitary District. *See Note* 5.																														
Add *								Under 5																						
								5 upwards																						
Deduct †								Under 5																						
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* Deaths occurring outside the Division or District among persons belonging thereto. † Deaths occurring within the Division or District among persons not belonging thereto.

(B)—TABLE OF POPULATION, BIRTHS, AND OF NEW CASES OF INFECTIOUS SICKNESS *coming to the knowledge of the Medical Officer of Health, during the year* 19   *, in the*   *Sanitary District of*   *; classified according to* DISEASES, AGES, *and* LOCALITIES.

Names of Localities adopted for the purpose of these Statistics; public institutions being shown as separate localities. *See Note* 2. (*a*)	Population at all Ages.		Registered Births. (*d*)	Aged under 5 or over 5. (*e*)	New Cases of Sickness in each Locality coming to the knowledge of the Medical Officer of Health.													Number of such Cases removed from their Homes in the several Localities for Treatment in Isolation Hospital.												
	Census 1891. (*b*)	Estimated to middle of yr. 19 . . (*c*)			1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13
									Fevers.													Fevers.								
					Small-pox.	Scarlatina.	Diphtheria.	Membranous Croup.	Typhus.	Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.			Small-pox.	Scarlatina.	Diphtheria.	Membranous Croup.	Typhus.	Enteric or Typhoid.	Continued.	Relapsing.	Puerperal.	Cholera.	Erysipelas.		
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State here whether "Notification of Infectious Disease" is compulsory in the District   Since when?   Besides the above-mentioned Diseases, insert in the columns with blank headings the names of any that are notifiable in the District, and fill the columns accordingly. State here the name of the Isolation Hospital used by the sick of the District. Mark (H) the Locality in which such Hospital is situated; and if not within the District, state where it is situated.

the articles of food, drink, or drugs are adulterated, cause a complaint to be made, and take the other proceedings prescribed by that Act.

(9) He shall give immediate notice to the Medical Officer of Health of the occurrence within the district of any contagious, infectious, or epidemic disease; and whenever it appears to him that the intervention of such officer is necessary in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall forthwith inform the Medical Officer of Health thereof.

(10) He shall, subject to the directions of the Sanitary Authority, attend to the instructions of the Medical Officer of Health with respect to any measures which can be lawfully taken by an Inspector of Nuisances under the Public Health Act, 1875, or under any Statute or Statutes, for preventing the spread of contagious, infectious, or epidemic disease of a dangerous character.

(11) He shall enter from day to day, in a book provided by the Sanitary Authority, particulars of his inspections, and of the action taken by him in the execution of his duties. He shall also keep a book or books, to be provided by the Sanitary Authority, so arranged as to form as far as possible a continuous record of the sanitary condition of each of the premises in respect of which any action has been taken under the Public Health Act, 1875, or under any other Statute or Statutes, and shall keep any other systematic records that the Sanitary Authority may require.

(12) He shall, at all reasonable times, when applied to by the Medical Officer of Health, produce to him his books, or any of them, and render to him such information as he may be able to furnish with respect to any matter to which the duties of Inspector of Nuisances relate.

(13) He shall, if directed by the Sanitary Authority to do so, superintend and see to the due execution of all works which may be undertaken under their direction for the suppression or removal of nuisances within the district.

(14) He shall, if directed by the Sanitary Authority to do so, act as officer of the said authority as local authority under the Contagious Diseases (Animals) Act, 1886, and any orders or regulations made thereunder.

(15) In matters not specially provided for in this Order he shall observe and execute all the lawful orders and directions of the Sanitary Authority, and the Orders of the Local Government Board, which may be hereafter issued, applicable to his office.

Under section 191 of the Public Health Act, 1875, the Medical Officer of Health may exercise the powers with which an Inspector of Nuisances is invested by that Act. Section 192 of the same provides that the same person may be both Surveyor and Inspector of Nuisances. In common with other sanitary officials, Medical Officers of Health, Surveyors, and Inspectors of Nuisances are prohibited by section 193 from being concerned in contracts with the Sanitary Authority. Section 2 of the Public Health (Members and Officers) Act, 1885, has to some extent qualified these provisions for exceptional cases; but independently of any of the above, very severe pains and penalties are imposed by the Public Bodies Corrupt Practices Act, 1889, on every person who solicits, receives, or agrees to receive corruptly any gift, fee, loan, or reward on account of any member, officer, or servant of any public body doing or forbearing to do anything in respect of any matter or transaction in which such public body is concerned.

The duties of county Medical Officers of Health and of Surveyors have not yet been authoritatively defined; neither have the qualifications of Inspectors of Nuisances in the provinces been prescribed.

In London, under section 106 of the Public Health Act, 1891, every Sanitary Authority is required to appoint one or more Medical Officers of Health for its district. The same person may, with the sanction of the Local Government Board, be appointed Medical Officer of Health for two or more districts; but, except in cases allowed by the Board, every such person must reside in that district, or within one mile of its boundary. A Medical Officer of Health in London may exercise any of the powers with which a Sanitary Inspector is invested; and his annual report to the Sanitary Authority must be affixed to the annual report of that authority.

The qualifications necessary for a Medical Officer of Health in London are similar to those required for similar offices in the provinces; and subject to the provisions of the Public Health (London) Act, 1891, as to existing

officers, the Local Government Board have the same powers as they have in the case of those in the rest of England and Wales, with regard to appointment, salary, duties, and tenure of office. This enactment (section 108) is, however, subject to the following provisions :—(*a*) a Medical Officer will be removable by the Sanitary Authority with the consent of the Local Government Board, or by that Board, and not otherwise ; (*b*) any such officer must not be appointed for a limited period only.

Every Sanitary Authority must appoint an adequate number of fit and proper persons as Sanitary Inspectors, and every one of them appointed after January 1, 1895, must be a holder of a certificate of such body as the Local Government Board may approve (such examinations are now conducted and certificates given by the Sanitary Inspectors Examination Board), or must have been, during three consecutive years preceding 1895, a Sanitary Inspector or Inspector of Nuisances of a district in London, or of an urban sanitary district out of London containing, according to the last census, a population of not less than 20,000 inhabitants.

The regulations prescribed by the Local Government Board as to the duties of Medical Officers of Health and Sanitary Inspectors in London are very similar in terms to those which apply to Medical Officers and Inspectors of Nuisances in the provinces. It is noticeable that, under the Acts in force outside the metropolis, no qualification is demanded for this latter office ; whereas, in London, such qualification is definitely explained (Public Health Act (London), 1891, section 108). It is probable that a similar provision will be inserted in any future consolidation of the Public Health Acts for the country generally.

In Scotland, every Local Authority shall appoint and pay one or more Medical Officers and Sanitary Inspectors.

A Medical Officer must be a registered practitioner, and may not now be appointed for a county, district, or parish with a population of 30,000 or upwards unless he holds a diploma in Public Health under the Medical Act, 1886 ; and no person may, except with the special consent of the Local Government Board, be appointed Sanitary Inspector of a county unless he has been, during the three consecutive years preceding his appointment, the Sanitary Inspector of a local authority under the Public Health (Scotland) Acts.

Burgh Commissioners must appoint a Sanitary Inspector and a Medical Officer of Health. The latter officer must be registered, and if appointed after May 15, 1894, must also have the special qualification required in counties since the beginning of 1893.

"No Medical Officer or Sanitary Inspector, whether for a county, landward district, or burgh, can be removed from office without the sanction of the Scottish Local Government Board."

The model bye-laws recommended by the Local Government Board for Scotland to the various Sanitary Authorities for regulating the duties of Medical Officers and Sanitary Inspectors do not materially differ from those of the English Board.

In Ireland.—By section 11 of the Public Health (Ireland) Act, 1878, the dispensary medical officers are *ex officio* Medical Officers of Health for their respective districts. In addition to the Medical Officers of Health, the Local Government Board for Ireland requires each rural Sanitary Authority, when directed by them, to appoint a consulting sanitary officer or a medical superintendent officer of health, and for either of these posts the medical officer of the union workhouse, or any other duly qualified medical practitioner, is eligible. The officials in England called Inspectors of Nuisances

or Sanitary Inspectors are in Ireland known as sanitary sub-officers, and for these posts the relieving officers, or the rate collectors of the several unions or other persons are eligible. Urban Sanitary Authorities are to appoint so many sanitary sub-officers as they, with the consent of the Local Government Board, may determine; also, when directed by the Board, they are to appoint one consulting sanitary officer or one medical superintendent of health, who must be a qualified medical practitioner; and an executive sanitary officer, with such qualification as the Sanitary Authority shall, with the consent of the Local Government Board, determine.

The appointments held by sanitary officers of both urban and rural authorities shall continue for such period as the Sanitary Authority may, with the approval of the Local Government Board, decide, or until the holder thereof die or resign. The regulations as to the duties of the several sanitary officers are similar to those of the English Local Government Board. There is provision in the Local Government (Ireland) Act, 1890, for the appointment of a surveyor, and power is given to a Sanitary Authority to employ a surveyor temporarily in order to execute any special work. There is no power given to Sanitary Authorities to combine for the appointment of sanitary officers. Parliamentary grants are made annually in recoupment of portions of the salaries of sanitary officers; the amounts recouped to local funds is one-half of the salaries.

There is no provision in the Irish Act prohibiting sanitary officials being concerned in contracts made with the authority for any of the purposes of the Public Health Act, nor does the Public Health (Members and Officers) Act, 1885, extend to Ireland. The Public Bodies Corrupt Practices Act, 1889, however, does apply to Ireland as well as to England.

DEFINITIONS.

There are certain definitions of terms in the various Sanitary Acts which give to those terms meanings which are not the same as the common meaning. The more important of these definitions are the following :—

Building.—This word has a very wide significance. It includes wooden structures on wheels, also those without foundations, but resting simply on the ground. Under the Infectious Diseases Notification Act, 1889, the term building applies to boats, vessels, ships, tents, vans, sheds, and other similar structures used for human habitation.

House.—Though not absolutely defined, the term "house" is so extended as to include schools, factories, and other buildings in which persons are employed. For a structure to be a "house" it is not necessary that persons reside in it.

Owner.—Under the Public Health Acts, the term "owner" means the person who, for the time being, receives the rack-rent of the lands or premises in connection with which the word is used, whether on his own account or as agent or trustee for any other person, or who would so receive the same if such premises were let at a rack-rent. By rack-rent is meant the rent that is not less than two-thirds of the full nett annual value of the property.

Under Part II., Housing of the Working Classes Act, the owner of a property is held to be any person or corporation who has at least a twenty-one years' interest in it.

Drain means any drain of, and used for the drainage of *one* building only, or premises within the same curtilage, and made merely for communi-

cating therefrom with a cesspool or like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

Sewers include sewers and drains of every description, except drains to which the word "drain," as above defined, applies. In other words, a sewer is a drain receiving the drainage of two or more buildings; and may be an open channel, such as a polluted water-course, as well as an underground culvert. Under the Metropolis Local Management Act, 1862, this distinction between drain and sewer is not accepted, but a combined drain is deemed to remain a drain. So again, in urban districts which have adopted section 19 of the Public Health Acts Amendment Act, 1890, the interpretation of "drain" is different. Whereas under the Public Health Act, 1875, if one or more houses drain into a common pipe, such common pipe or combined drain is a sewer; but under section 19 of the Amended Act this common pipe is deemed to be a sewer only if all the houses *belong to one owner;* if they belong to more than one owner, then the combined drain is a drain repairable at the owners' expense, and not a sewer repairable at the expense of the Sanitary Authority.

As will be explained later, when discussing the law relating to house drainage and sewerage, these definitions are far from satisfactory, the terms being variously interpreted by different justices.

Canal.—Under the Canal Boats Acts, 1877 and 1884, the term "canal" includes any river, lake, water, or inland navigation "being within the body of a county, whether it is, or is not, within the ebb or flow of the tide."

Canal Boat.—This includes any and every vessel, however propelled, used for conveyance of goods along a canal, as above defined, but does not include a ship registered under the Merchant Shipping Act, 1894, unless the Local Government Board orders otherwise, which it may do on the representation of a Sanitary Authority or any of its inspectors.

Curtilage is defined as a "court-yard, backside or piece of ground lying near to a dwelling-house."

Slaughter-house includes the buildings and places commonly called slaughter-houses and knackers' yards, and any building or place used for slaughtering cattle, horses, or animals of any description.

Sanitary convenience includes urinals, water-closets, earth-closets, privies, ashpits, and any similar convenience.

Ashpit includes any ashtub or other receptacle for the deposit of ashes, fæcal matter, or refuse.

Lands and **premises** include messuages, buildings, lands, easements and hereditaments of any tenure.

Dwelling-house means any inhabited building, and includes any yard, garden, outhouses, and appurtenances belonging thereto, or usually enjoyed therewith, and includes the site of the dwelling-house as so defined.

Street includes any highway (not being a turnpike road), and any public bridge (not being a county bridge), and any road, lane, footway, square, court, alley, or passage, whether a thoroughfare or not (Public Health Act, 1875, section 4). The Public Health (London) Act, 1891, section 141, adds to this definition of a street the words "whether or not there are houses in such street." Under the Housing of the Working Classes Act, 1890, section 29, the word "street" is restricted to a road, &c., with houses built in it, and does not include highways or roads without houses.

Earth-closet is defined "as any place for the reception and deodorisation of fæcal matter, constructed to the satisfaction of the local authority."

BYE-LAWS AND REGULATIONS.

In respect of certain matters, and under certain conditions expressly stated in the various Acts dealing with the Public Health, Sanitary Authorities may make bye-laws having the force of law. These bye-laws are intended rather to supplement than to summarise, vary, or supersede the express provisions of the statute law. All bye-laws made by Sanitary Authorities under and for the purpose of the Public Health Acts must be under their common seal; and any such bye-law may be altered or repealed by a subsequent bye-law made pursuant to the provisions of the Acts. But no bye-law is of effect if repugnant to the laws of England or to the provisions of the Acts. A Sanitary Authority may, by any bye-laws made by it, impose such reasonable penalties as it thinks fit, not exceeding £5 for each offence, and, in the case of a continuing offence, a further penalty not exceeding 40*s*. for each day after written notice of the offence; but all such bye-laws imposing any penalty must be so framed as to allow of the recovery of any sum less than the full amount of the penalty. Bye-laws do not take effect unless and until they have been confirmed by the Local Government Board, who have power to allow or disallow the same as they think proper. The bye-laws, when confirmed, must be printed and hung up in the office of the Sanitary Authority, and a copy of them must be delivered to any ratepayer of the district who applies for them (see Public Health Act, 1875, sections 182 to 185).

Some bye-laws must be made by a local authority; there are others which may be made by both urban and rural authorities, and others also which urban Sanitary Authorities are alone empowered to make. In the greater number, the power to make them is permissive.

Regulations differ somewhat from bye-laws, because, with few exceptions, they do not require the approval of the Local Government Board. They may be simply passed as a resolution at a meeting of the authority, and may be amended or rescinded at a subsequent meeting. In certain cases, as, for instance, under section 125, Public Health Act, 1875, relating to the removal to hospital of infected persons brought by ships, a regulation, just like a bye-law, has to be approved by a superior authority, and its breach involves liability to a money penalty.

Urban Sanitary Authorities are empowered to make bye-laws in respect of the following:—

1. *Common Lodging-houses.*—For fixing and varying the number of lodgers; for the separation of the sexes; for promoting cleanliness and ventilation; for giving of notices and taking precautions in the case of infectious diseases; for the general well-ordering and sanitation of such houses (Public Health Act, 1875, section 80).

2. *Cleansing and Scavenging.*—For the cleansing of footways; for the removal of house refuse; for the prevention of nuisances arising from snow, dust, ashes, rubbish, and the keeping of animals (Public Health Act, 1875, section 44).

3. *Tenement Houses.*—For regulating the number of persons and separation of the sexes; for promoting cleanliness, ventilation, and prevention of the spread of infectious diseases; besides the general well-ordering of such houses (Public Health Act, 1875, section 90). So far as relates to seamen's lodging-houses, the power to make bye-laws is derived from the Merchant Shipping Act, 1894, section 214.

4. *New Streets and Buildings.*—With respect to the level, width, con-

struction, and sewerage of new streets; and to the structure, stability, ventilation, general sanitary arrangement, alteration, removal, and closure of buildings unfit for habitation (Public Health Act, 1875, section 157, and Part III., Public Health Amendment Act, 1890).

5. *Slaughter-houses.*—For the licensing, registering, and inspection of slaughter-houses and knackers' yards; for ensuring their cleanliness and proper supply of water, as well as to prevent cruelty therein (Public Health Act, 1875, section 169).

6. *Markets and Fairs.*—For the prevention of nuisances, the inspection of slaughter-houses and the daily removal of refuse, the prevention of the exposure or sale of unwholesome food, and various other purposes (Public Health Act, 1875, section 167).

7. *Offensive Trades.*—To control, prevent, or lessen the injurious effects of various or any offensive trades (Public Health Act, 1875, section 113).

8. *Hop- and Fruit-pickers.*—For securing these workers decent lodgings and accommodation while so engaged (Public Health Act, 1875, section 314, and Public Health (Fruit-pickers) Act, 1882).

9. *Tents and Vans.*—For the promotion of cleanliness, prevention of nuisances in connection with, and the spread of infectious disease by the occupants of these structures (Housing of the Working Classes Act, 1885, section 9).

10. *Mortuaries and Cemeteries.*—For the regulation of charges, and management (Public Health Act, 1875, section 141, and the Public Health (Interments) Act, 1879).

11. *Open Spaces.*—For the regulation of public grounds and walks, including churchyards or burial-grounds over which the Sanitary Authority may have control (Public Health Act, 1875, section 164, and the Open Spaces Act, 1887).

12. *Employment of Children.*—Urban authorities with a population of 20,000, Boroughs over 10,000, and County Councils can make bye-laws regulating the employment of children under 14 (not under the Factory or Mines Acts) and street trading by persons under 16 (Employment of Children Act, 1903).

13. The Municipal Corporations Act, 1882, section 23, gives power to municipalties or Borough Councils to make bye-laws for the *suppression and prevention of nuisances* not already punishable in a summary manner by any other Act in force throughout the borough. County Councils have similar powers under the Local Government Act, 1888, section 16.

14. Urban authorities can further make bye-laws under the Housing of the Working Classes Act, 1890, for the regulation of all buildings provided under that Act or the Acts which it supersedes.

15. For *means of escape from fire* in factories and workshops under section 15, Factory and Workshop Act, 1901.

Rural Sanitary Authorities have similar powers for making bye-laws in respect of the following:—

(1) *Private scavenging*, (2) *Common lodging-houses*, (3) *Tenement houses and Seamen's lodging-houses*, (4) *Hop- and fruit-pickers*, (5) *Tents and vans*, (6) *Mortuaries, and* (7) *under the Housing of the Working Classes Act*, 1890. Further, by adopting portions of the Public Health Acts Amendment Act, 1890, which are not expressly limited to urban districts, rural Sanitary Authorities can make certain bye-laws as to *new and old buildings*. The Local Government Board may confer on them any other powers as to bye-laws which the Public Health Acts give to urban authorities (Public Health Act, 1875, section 276.)

Every Sanitary Authority *must* make bye-laws as to common lodging-houses; every urban Sanitary Authority *must* do the same as to slaughter-houses; the exercise of power as to other bye-laws is optional.

The London County Council have power to make bye-laws for the regulation of the plans, levels, width, surface, inclination and materials of new streets and roads; for the plan and sites of buildings; as to the dimensions, form, construction, cleansing and repairing of pipes, drains, and traps connected with sewers; and as to the construction, ventilation and cleansing of sewers (London Building Act, 1894, section 164, and certain unrepealed clauses of the Local Management Acts).

Also under the Public Health (London) Act, 1891, for regulating the conduct of offensive trades, and the structure of the premises (section 19). For prescribing the times for removal of any fæcal or offensive matter in or through London, so as to avoid the creation of a nuisance (section 16), As to the closing of cesspools and privies, the removal and disposal of refuse, and as to the duties of the occupier of any premises in connection with house refuse (section 16). As to water-closets, earth-closets, ashpits, cesspools, receptacles for dung, and the proper accessories thereof in connection with buildings (section 39). The power to make bye-laws under section 19 is permissive, but under sections 16 and 39 is compulsory. Also as to tenement houses (section 94).

The Metropolitan Sanitary Authorities *must* make bye-laws for the control of nuisances arising from snow, ice, salt, dust, rubbish, ashes, carrion, fish, or filth in the streets; or from offensive matters running from any manufactory, brewery, slaughter-house, or dung-hill; for the prevention of keeping animals on any premises in such place or manner as to be a nuisance or dangerous to health; and as to the paving of yards and open spaces in connection with dwelling-houses (section 16). For the keeping of water-closets supplied with sufficient water for their effective action (section 39). For the cleansing and protecting of all cisterns, tanks, &c., used for storing water for domestic purposes, drinking, or the manufacture of beverages (section 50).

The same authorities *may* make bye-laws for the removal to hospital or detention therein of persons suffering from infectious disease (section 66). For preventing the fouling of tents, vans, sheds, and similar structures used for human habitation, and the spread of infectious disease by the inhabitants thereof (section 95). In relation to tenement houses, bye-laws are made under section 8 of Housing of the Working Classes Act, 1885. These same authorities must also enforce any bye-laws made by the County Council under sections 16 and 39 of the Public Health (London) Act, 1891.

In the city of London, similar powers are vested in the corporation under the City of London Sewers Acts, 1848 and 1851, the Public Health (London) Act, 1891, the Gardens in Towns Protection Act, 1863, the Metropolitan Open Spaces Acts, 1877 and 1881, and the Open Spaces Act of 1887.

Under the Dairies Order, 1885, any Sanitary Authority may make regulations for any of the following purposes:—(*a*) For the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilating draining, cleansing and water-supply of dairies and cow-sheds; (*c*) for prescribing precautions to be taken by purveyors of milk against infection; (*d*) for securing the cleanliness of milk stores, milk shops, and milk vessels used for containing milk for sale.

A Sanitary Authority, subject to approval by the Local Government Board, may make regulations for the removal to hospital and detention there as long as necessary of all persons who may be brought within their

district by either boat or ship, and who may be infected with an infectious disease (Public Health Act, 1875, section 125). They have also power to make regulations for the management of places provided by them for making *post-mortem* examinations ordered by a coroner (section 143).

The Local Government Board has power to make regulations under sections 130 and 134 of the Public Health Act, 1875, in relation to cholera and other dangerous infectious diseases.

The provisions as to making bye-laws in Scotland and Ireland are somewhat similar to those above mentioned. Where offering any marked differences from the English procedures, the fact will be indicated in the following pages.

From time to time the Local Government Board have prepared and issued "Model Bye-laws" to serve as guides to Sanitary Authorities when seeking to frame bye-laws. As these models have been very generally adopted, subject to occasional modifications, by various Sanitary Authorities, a summary of them will be given under each heading where, in respect of certain matters, the Public Health Acts give the Sanitary Authority power to frame them. Supplementary to these model bye-laws, various regulations in regard to the management of mortuaries and cemeteries have been issued by the Home Secretary; these will be detailed in their appropriate places.

While the main basis of so-called sanitary law as now in force in the different parts of the United Kingdom are the various Public Health Acts of 1875 (England and Wales), 1878 (Ireland), 1891 (London), and 1897 (Scotland), there are in addition a large number of other Acts of Parliament, which in various ways strengthen or otherwise modify the foregoing. This condition of affairs renders naturally the whole subject of sanitary law a matter of some complexity. In the following pages we have deemed it more convenient to consider rather the general effect of these various legislative enactments, as a whole, upon each sanitary matter of importance, than to analyse each Act separately. Therefore, wherever possible, the bearing of the various legal enactments upon different sanitary problems is summarised at the end of each section. At the same time, references will be made to the peculiarities of the legislation in force in the different parts of the kingdom; that is to say, how far the law, as affects England and Wales, differs from that in London, and how far that of Scotland and Ireland differs from either, both, or each other. By this arrangement it is hoped that a comprehensive view may be obtained, consistent with the space at our command, of the general bearing of the law in respect of sanitary matters in all parts of the United Kingdom.

While the greater part of sanitary law can be summarised and discussed in connection with its appropriate subject, there are several topics of little scientific interest, which are mainly of importance only so far as concerns the definite legal provisions relating to them. These we propose to discuss in this chapter; they relate to such matters as Nuisances, Parks, Commons and Open Spaces, Cleansing of Persons, the Control of Midwives, the Employment of Young Persons in Shops, the Protection of Infant Life, and the Employment of Children. In respect of all these matters, a Sanitary Authority has certain legal responsibilities.

NUISANCES.

In a legal sense, nuisances are of two chief kinds, namely, (1) nuisances at common law; (2) nuisances under the Public Health Acts, commonly called "statutory nuisances."

At common law a nuisance may be public, private, or both. *A public nuisance* is thus defined by Stephen in his *Digest of Criminal Law* (art. 176):—"An act not warranted by law, or an omission to discharge a legal duty, which act or omission obstructs, or causes inconvenience or damage to the public in the exercise of rights common to all His Majesty's subjects." As examples of public nuisances may be quoted the pollution of the air by smoke or by noxious fumes from a factory, obstruction of a highway, and exposure of infected persons in the public way. *A private nuisance* is anything done to interfere with the proprietary rights of another in land, not amounting to a trespass (Wynter-Blyth). As examples of private nuisances one may mention special annoyance from steam-hammers or engines making a noise, and the special annoyance from smoke. *A mixed nuisance* is obviously a nuisance which belongs to both of the above-mentioned varieties.

Statutory nuisances under the Public Health and Sanitary Acts alone concern the officers of Sanitary Authorities. As relating to the Public Health, these statutory nuisances have been well defined by Wynter-Blyth as being "something which either actually injures, or is likely to injure, health, and admits of a remedy, either by the individual whose act or omission causes the nuisance, or by the local authority." It is important to bear in mind that in the Public Health Act sense, as now understood and interpreted, the idea of a nuisance embraces future as well as present consequences. The Public Health Law, in respect of nuisances, may be summarised, for the various parts of the United Kingdom, in the following manner:—

In England and Wales.—The provisions of the Public Health Act, 1875, sections 91 to 111, apply to every urban and rural sanitary district, and are "deemed to be in addition to, and not to abridge any right, remedy, or proceeding under any other provisions of the Act, or under any other Act, or at law or in equity." But no person may be punished for the same offence both under these provisions and under any other law or enactment. Under this Act of 1875 "nuisance" is regarded as likely to arise in connection with:—(*a*) Sewers, sections 18 and 19; (*b*) Sewage, section 27; (*c*) Construction of drains, closets, ashpits, and cesspools, sections 40 and 41; (*d*) In connection with snow, filth, dust, ashes, and rubbish, section 44; (*e*) Swine, pig-styes, and stagnant water in cellars, or the overflowing of privies and cesspools, section 47; (*f*) Offensive trades, sections 112, 113, and 114.

In regard to some of these cases, remedies are given by other provisions of the Act, more particularly by sections 41, 49, and 50. It will rest with the Sanitary Authority to determine under which provisions they will proceed, having regard to the circumstances. The main section dealing with nuisances is, however, section 91, which defines the following to be nuisances to be dealt with summarily under the Act:—

(1) Any premises, including buildings and lands, in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, water-course, privy, urinal, cesspool, drain, or ashpit so foul, or in such a state as to be a nuisance or injurious to health. (3) Any animal so kept as to be a nuisance or injurious to health. (4) Any accumulation or deposit which is a nuisance or injurious to health. (5) Any house, or part of a house, so overcrowded as to be dangerous or injurious to the health of the inmates, whether or not members of the

same family. (6) Any factory, workshop, or workplace, not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as practicable any gases, vapours dust, or other impurities generated in the course of the work carried on therein, that are a nuisance or injurious to health, or so overcrowded as to be dangerous or injurious to the health of those employed therein. (7) Any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever, and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.

In defining these nuisances, the same section, however, provides that there is no penalty if the accumulation or deposit mentioned in (4) is necessary for, and has not been kept longer than is necessary for, the carrying on of any business or manufacture, and if the best available means have been taken for preventing injury to the public health. The provisions of subsection (6) apply to all buildings, including schools, factories, and workshops, except such as are subject to the special provisions, relating to cleanliness, ventilation, or overcrowding, of the Factories and Workshop Acts. In respect of (7) there is no penalty if the Court is satisfied that the fireplace or furnace is constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended to by the person in charge thereof. Under the smoke sections it is not necessary in taking action to prove anything with regard to health, it being sufficient to prove that on such and such a day and hour the chimney emitted *black* smoke. Urban Sanitary Authorities have some other powers with regard to smoke under section 171 of this Act, and under the Railway Regulation Act, 1868, and the Highways and Locomotives Act of 1878.

For interpreting the term " overcrowded " in subsection 5 of section 91, Public Health Act, 1875, a sanitary officer usually takes as his guide the minimum standards laid down by the Local Government Board in their byelaws, namely, 400 cubic feet for rooms in which persons both live and sleep, and 300 cubic feet for rooms solely used for the waking life of the tenants. In the event of a second conviction for overcrowding within three months, the Court may order the closing of the premises (section 109). Another point to be noted in connection with this subsection is that the words " tent, van, shed, or similar structure " may be included within it by section 9 of the Housing of the Working Classes Act, 1885.

Unfenced quarries and abandoned coal-mines are deemed to be nuisances under section 91 of the Public Health Act, 1875, by the Quarry (Fencing) Act of 1887, and the Coal-Mines Regulation Act, 1887.

It is the duty of every Sanitary Authority to cause their district to be inspected for the detection of nuisances and to enforce the provisions of the Public Health Act, 1875, in order to abate the same (section 92), but the authority may be put in motion by any person aggrieved, or by any two inhabitant householders of such district, or by any officer of the Sanitary Authority, or by the relieving officer, or by any police officer (section 93). If satisfied of the existence of a nuisance, the Sanitary Authority is required by the Act to serve a notice on the person responsible, or, if he cannot be found, on the owner or occupier of the premises on which the nuisance arises, requiring him to abate the same within a time to be specified in the notice, and to execute such works as are specified in the notice as being necessary. Where the nuisance arises from the want or defective construction of any structural convenience, or where there is no occupier, the notice must be served on the owner. If the person causing the nuisance cannot be found, and the owner or occupier be not responsible for its occurrence, the Sanitary Authority may themselves abate the same without further order (section

94). On non-compliance with the notice, or if the nuisance, although abated, is likely to recur, the Sanitary Authority may apply to a justice, who must thereupon summon the person responsible to appear before a Court of summary jurisdiction (section 95). If the Court is satisfied that the alleged nuisance exists, or that, although abated, it is likely to recur on the same premises, it must make an order requiring him to comply with the notice or prohibiting the recurrence of the nuisance, and directing the execution of any necessary works. The Court may further impose a penalty not exceeding £5 (section 96). Where the nuisance is such as to render the house unfit for habitation, the Court may order the house to be closed, and may cancel this by a further order when satisfied that the house has been made fit for habitation (section 97). Any person not obeying the order of the Court, or failing to use diligence, is liable to a penalty not exceeding 10*s*. per day during his default ; and the Sanitary Authority may carry out the order and charge him with the expenses (section 98). Where the person responsible for the nuisance cannot be found, the order of the Court may be carried out by the Sanitary Authority ; and any matter or thing removed by the authority in abating any nuisance may be sold (sections 100, 101). Where any nuisance under the Act is caused by the acts or defaults of two or more persons, the Sanitary Authority may institute proceedings against any one or more of such persons (section 255). Where a nuisance within a district is caused by some act or default beyond its limits, the Sanitary Authority may institute proceedings, provided that these be taken before a Court having jurisdiction in the district where the act or default is alleged to be committed or take place (section 108).

For the purpose of the provisions of this Act of 1875 relating not only to nuisances but also to infectious diseases and hospitals, any ship or vessel lying in any water within the district of a Sanitary Authority is subject to their jurisdiction as if it were a house. If in any other water, it is deemed to be within such district as the Local Government Board may prescribe, and in the absence of any such prescription, then within the nearest sanitary district (section 110). The master or other officer in charge of any such ship will be deemed to be the occupier ; but these provisions do not apply to any of His Majesty's ships, or to those of any foreign government.

The Sanitary Authority and their officers have rights of entry between 9 A.M. and 6 P.M. upon private premises, and, in the case of a nuisance arising in respect of any business, at any hour when such business is in progress. If admission is refused, a justice's order may be obtained (sections 102, 103).

Where Sanitary Authorities fail to take proceedings for abatement of nuisances, individuals may obtain a remedy in one of three ways, either (1) by complaining to the Local Government Board, who may issue an order, enforceable by mandamus in a High Court of Justice (section 299); or (2) on it being proved to the satisfaction of the Local Government Board that a Sanitary Authority have made default in relation to nuisances under the Public Health Act, 1875, that Board may authorise any police officer, acting within the district of the defaulting authority, to institute proceedings which the defaulting authority might institute with regard to such nuisance (section 106) ; or (3) any individual may complain direct to a justice as to the existence of a nuisance, and the Court may make orders, penalties for disobedience of orders, &c., as in the case of a complaint relating to a nuisance made to a justice by a Sanitary Authority (section 105). This latter mode of procedure is obviously the most expeditious for any individual to take where he feels aggrieved by the neglect of a Sanitary

Authority to take proceedings, and where the existence of a nuisance within the meaning of the Act is clear.

In London.—The powers and duties of the Borough Councils in the capacity of Sanitary Authorities in London, with respect to nuisances under the Public Health (London) Act, 1891, in the main correspond with those relating to nuisances under the Public Health Act, 1875, as explained under England and Wales. But they embody several amendments and extensions of the law which have materially strengthened the hands of the Sanitary Authorities in London in dealing with nuisances. Section 2 of the London Act extends the definition of "nuisance," making it include not only that which is *injurious* to health, but also that which is *dangerous* to health. It also makes it include any cistern, water-closet, earth-closet, or dung-pit, so foul or in such a state as to be a nuisance or injurious or dangerous to health, and any such absence from premises of water-fittings as is a nuisance by virtue of section 3 of the Metropolis Water Act, 1871. Further, *any person* may give information to the Sanitary Authority of a nuisance, and it is the *duty* of every officer of the authority and of the relieving officer so to do, and to give written notice to the persons who may be required to abate it.

In giving notice requiring abatement of a nuisance, it is *optional* to specify the works to be executed; also, where the persons responsible for causing the nuisance cannot be found, the Sanitary Authority may not only themselves abate the nuisance, but also do what is necessary to prevent its recurrence. In cases of overcrowding, the Sanitary Authority *must* take proceedings to abate the nuisance. The penalty for wilful nuisance or non-abatement is a fine of £10 for each offence, whether an order to abate it or prohibiting its recurrence is made or not (section 4). Similarly, the maximum fines for failing to comply with an order for the abatement of a nuisance or for acting contrary to a prohibition order are increased from the amounts fixed by the Public Health Act, 1875, to 20*s*. a day and 40*s*. a day respectively during default or contrary action, as the case may be (section 5 (9)). Wilful damage to drains, water-closets, &c., so as to create nuisances, involve a fine not exceeding £5 (section 15). Groundless appeals to Quarter Sessions against nuisance orders are checked by daily fines of 20*s*. (section 6 (3) (4)).

The Sanitary Authority, moreover, are required by section 16 of the London Act to make bye-laws for the prevention of nuisances arising from (1) any snow, ice, salt, dust, ashes, rubbish, offal, carrion, fish, filth, or other matter in the street; (2) from any offensive matter running out of any manufactory, brewery, slaughter-house, knackers' yard, butcher's or fishmonger's shop, or dung-hill, into any uncovered place, whether or not surrounded by a wall or fence; (3) from keeping of animals; (4) as to the paving of yards and open spaces in connection with dwelling-houses. Under section 6, Local Government Act, 1899, it shall be the duty of each Borough Council to enforce within their borough the bye-laws and regulations for the time being in force with respect to dairies and milk, and with respect to slaughter-houses, knackers' yards, and offensive businesses. It is, moreover, the duty of the Sanitary Authority to enforce any bye-laws made, in respect of these matters, by the County Council.

As regards the prevention of smoke, section 24 of the Public Health (London) Act, 1891, corresponds closely with section 91 of the Act of 1875; but the main provisions against nuisances arising from smoke in the metropolis are contained in section 23 of the London Act of 1891, which provides that "every furnace employed in the working of engines by steam, and

every furnace employed in any public bath or wash-house, or in any mill, factory, printing-house, dye-house, ironfoundry, glass-house, distillery, brew-house, sugar refinery, bakehouse, gasworks, waterworks, or other building used for the purpose of trade or manufacture (although a steam-engine be not used or employed therein) shall be constructed so as to consume and burn the smoke arising from such furnace." Sanitary Authorities *must* carry out these provisions of this section, and, moreover, any information under it is not to be laid except under the direction of a Sanitary Authority. This section extends to the Port of London, where it must be enforced by the port Sanitary Authority, which is the City Corporation.

In Scotland.—The statutory enumeration of nuisances which may be summarily dealt with, as contained in the Public Health (Scotland) Act, 1897, follows closely on the lines of the English Act of 1875 or the London Act of 1891.

Except in certain cases as regards fireplaces, furnaces, and chimneys sending forth smoke so as to be injurious to health, and also churchyards or cemeteries so situated, or so crowded with bodies, or so conducted, as to be offensive or injurious to health, the summary decision of a sheriff, magistrate, or justice upon the alleged existence of a nuisance is final.

As regards manufactories, trades, and businesses injurious to the health of the neighbourhood, or so conducted as to be offensive or injurious to health, or any collection of bones or rags, as well as factories not under any general Act for the regulation of factories or bakehouses, a medical certificate or requisition by ten inhabitants is required before the justice can give an interdict of the nuisance. The sheriff, magistrate, or justice may order remedial works to be carried out, or ordain the local authority to do so and to recover expenses from the owner of the premises or person responsible for the nuisance. There are no saving clauses at all corresponding to those in the English Act.

A County Council, subject to the approval of the Local Government Board for Scotland, may make bye-laws " for prevention and suppression of nuisances not already punishable in a summary manner by virtue of any Act in force throughout the country"; and Burgh Commissioners, subject to the approval of the Local Government Board, have similar powers in respect of the burghs (Burgh Police (Scotland) Act, 1892).

If a local authority refuse to enforce the provisions of the Public Health (Scotland) Act as to nuisances or otherwise, any two householders or the inspector of the poor, or the local procurator-fiscal, or the Local Government Board may apply to the sheriff for a summary decision and decree. The subsequent course of action is similar to that under similar circumstances in England.

In Ireland.—The nuisance prevention provisions are almost, if not quite, identical in the Public Health (Ireland) Act, 1878, section 107 *et seq.*, with those of the English Act of 1875; consequently, the explanations already given as to the law of nuisances in England and Wales hold good for that in Ireland. The Coal-Mines Regulation Act, 1887, applies to Ireland, but the Quarry (Fencing) Act of the same year does not apply.

PARKS, OPEN SPACES, AND COMMONS.

In England and Wales.—The Public Health Act, 1875, section 164, empowers urban Sanitary Authorities to provide and regulate, by means of bye-laws, public parks and pleasure grounds. To pleasure grounds,

provided under this enactment, the public have a right of admission free of charge; but in consequence of the advantages which had been found to result from the insertion in local Acts of provisions to close these parks and grounds at certain times, and to make charges of admission thereto, section 44 of the Public Health Acts Amendment Act, 1890, has enabled the urban Sanitary Authorities of districts in which Part III. of that Act has been adopted to close to the public, on certain days, the public parks, and grant their use to any public charity, or institution, or society, or show, gratuitously or on payment. Section 45 of the same Act has extended the powers of urban authorities under section 164 of the 1875 Act, to enable them to contribute towards the cost of laying out, planting, and improving, or even of purchasing lands for purposes of public parks and pleasure grounds.

By section 8 (1) (*d*) of the Local Government Act, 1894, Parish Councils can exercise with respect to any recreation ground, village green, open space, or public walk for the time being under their control, or to the expense of which they have contributed, such powers as may be exercised by urban Sanitary Authorities under section 164 of the Public Health Act, 1875.

The Open Spaces Act, 1906, which consolidates and supersedes all previous enactments relating to open spaces, gives to all urban authorities and to every rural authority, invested by order of the Local Government Board with powers under the Act, facilities for the acquisition, maintenance and regulation of open spaces, including disused burial-grounds, for the use of the public.

Urban Sanitary Authorities of districts containing a population of more than 5000 inhabitants, at the last published census, have powers in connection with the preservation of commons either wholly or partly in their district or within six miles thereof, under section 8 of the Commons Act, 1876.

In London.—The Gardens in Towns Protection Act, 1863, enables the County Council and the Corporation of London, in the respective areas over which they have jurisdiction, to take over, on the request of the persons entitled thereto, the right to require any garden or ornamental ground to be kept and maintained as such, and to protect it from being built upon. Such gardens may be managed by a committee of the rated inhabitants of the houses surrounding the same, at the cost of the Borough Councils, or be vested in the Borough Councils subject to the approval of the County Council, or be managed by the Corporation, if within the city. Under the Open Spaces Act, 1906, further powers are given to the County Council and Corporation of London to acquire, maintain, and regulate open spaces and disused burial-grounds within their respective spheres of jurisdiction. In respect of these powers and duties they have power to make bye-laws. All powers and duties conferred upon the County Council may be exercised and performed by any Borough Council. They have, further, power in certain cases to rate inhabitants of squares, crescents, or circuses for maintenance of gardens (Metropolis Management Act, 1855, section 239).

As regards schemes under the Metropolitan Commons Act, 1878, the County Council, in respect of any common situate within the metropolis, have the same power to oppose inclosure, also to purchase and hold, with a view to prevent the extinction of the "common rights," any saleable rights in common, or any tenement of a commoner having annexed thereto rights of common, as is conferred by section 8 of the Commons Act, 1876, upon an urban Sanitary Authority in respect of a suburban common. So, by the Corporation of London (Open Spaces) Act, 1878, the Corporation can acquire

by purchase, gift, or otherwise the freehold or interest in common lands not within the Metropolis Management Act, but within twenty-five miles of the city, and all rights over such lands.

In Scotland the Open Spaces and Commons Acts do not apply, but a burgh rate may be applied in maintaining or defending rights in commons or open spaces, and the Burgh Commissioners may provide and regulate the same by bye-laws (Burgh Police Act, 1892, sections 307, 308, 316). By the Public Parks (Scotland) Act, 1878, and the Secretary for Scotland Act, 1885, the Local Authorities may " purchase, or take on lease, lay out, plant, improve, and maintain lands for the purpose of being used as parks, public walks, or pleasure grounds," as well as borrow and rate, and also regulate their use by bye-laws, to be approved by the Secretary for Scotland. A further power of acquiring land within two miles outside of a burgh " for a pleasure ground or place of public resort or recreation " has been conferred on Burgh Commissioners by the Burgh Police Act, 1892.

In Ireland.—There is no provision in the Irish Public Health Act analogous to section 164 of the corresponding English Act, but similar powers to those contained in the latter are provided in the Open Spaces Act, 1906, which applies to Ireland. Section 44 of the Public Health Amendment Act, 1890, applies also to urban Sanitary Authorities in Ireland who have adopted Part III. of the Act.

Besides the power of establishing and maintaining public parks and grounds given by the above-mentioned Acts, other similar powers are given to Towns Commissioners and Municipal Authorities of towns with a population exceeding 6000 inhabitants by the Towns Improvement (Ireland) Act, 1854, and the Public Parks (Ireland) Act, 1869; the powers therein given include the borrowing of money for the purposes of the Acts, and the appointment of committees to regulate these public recreation grounds by means of bye-laws. The Commons Act, 1876, does not extend to Ireland.

CLEANSING OF PERSONS.

In England and Wales.—The legal enactments bearing upon this question are the four Baths and Wash-houses Acts of 1846, 1847, 1878, and 1882, together with the Cleansing of Persons Act, 1897. The Baths and Wash-houses Acts are all adoptive, and under section 10, Public Health Act, 1875, urban Sanitary Authorities can adopt them, the authority having all the powers, rights, duties, capacities, liabilities, and obligations as to the formation, maintenance, regulation, and management of baths and wash-houses within their district. In rural parishes these Acts can only be adopted by the Parish Meeting; and the Parish Council, if there is one, is the authority to carry them into effect. Bye-laws may be framed by the controlling authority for the maintenance of order, decency, and cleanliness in all baths and wash-houses, the Local Government Board having issued a series of models for their guidance in this respect.

Where the Acts have been adopted, the expenses of the authority in their execution, so far as the baths and wash-houses are not self-supporting, will be borne in the same manner as their expenses under the Public Health Act, 1875; and the authority will have the same powers of borrowing in respect of these expenses as in the case of expenses under that Act.

By the Cleansing of Persons Act, 1897, a Sanitary Authority has the power to permit any person who shall apply, on the ground that he is infested with vermin, to have the use, free of charge, of any apparatus which

the authority possess for cleansing the person and clothing from vermin. The use of such apparatus shall not be considered to be parochial relief or charitable allowance to the person using the same, and no such person or person's parent shall by reason thereof be deprived of any right or privilege or be subject to any disability or disqualification. Any reasonable expenses incurred for this purpose or for providing suitable buildings and apparatus may be defrayed out of any rate or fund applicable by the authority for general sanitary purposes or for the relief of the poor. The term Sanitary Authority, for this purpose, means the Council of any County Borough, the District Council of any district and any Board of Guardians.

In London.—The Baths and Wash-houses Acts may be adopted in any metropolitan parish by the Borough Councils, with the approval of the Local Government Board, and where this is done Commissioners selected by the Borough Councils from among the ratepayers must be appointed to put the Acts into execution. The expenses of carrying the Baths and Wash-houses Acts into execution in each parish, to such amount as may from time to time be sanctioned by the Borough Councils, are chargeable upon the moneys applicable to the relief of the poor in the parish, so far as they are not met by the revenue from the baths, wash-houses, and bathing-places provided by the Commissioners.

By their Baths and Wash-houses Act of 1895, the Corporation of London have power to act as Commissioners of Baths and Wash-houses under the Acts 1846 to 1882 for the city, and to erect, or acquire, control, regulate, and make bye-laws for any such baths, wash-houses, or bathing-places as they may deem necessary within the city of London.

The Cleansing of Persons Act, 1897, applies to London, and the authority to put it in action is any Sanitary Authority as defined by the Public Health (London) Act, 1891.

In Scotland the Baths and Wash-houses Acts do not apply, consequently the landward authorities have no power to provide such accommodation for the public. But in the burghs the Commissioners may provide such bathing-places with full power to regulate them, subject only to the condition that there must be at least twice as many baths for the working classes as there are baths of the better class (Burgh Police Act, 1892, sections 309 to 314).

Under section 126, Public Health (Scotland) Act, 1897, the local authority may, if they think fit, provide and gratuitously supply water for any public baths or wash-houses established otherwise than for private profit or supported out of the rates.

The Cleansing of Persons Act, 1897, applies to Scotland, and Sanitary Authority means any local authority under the Public Health (Scotland) Act, 1897, and any amending Acts, but the authority shall not erect buildings for the purposes hereof, except with the sanction of the Local Government Board for Scotland.

In Ireland there is only one Baths and Wash-houses Act, namely, that of 1846. This Act is practically the same as that of the English one of the same year. Further, by the Public Health Act, 1878, urban Sanitary Authorities, who have adopted the former Act, are the controlling authorities for such baths and wash-houses within their district, just as is the case with English urban authorities under the English Public Health Act, 1875. In rural districts, the Baths and Wash-houses Act cannot be put in force except in municipal towns, not being urban Sanitary Districts, which are situated therein. The general provisions as to expenses, borrowing of money, and making of bye-laws are similar to those in force in England.

Some powers to provide baths, &c., are given to Commissioners of towns constituted under the Towns Improvement (Ireland) Act, 1854, by section 55 of that Act, which incorporates sections 136 to 141 of the Towns Improvement Clauses Act of 1847.

In the application of the Cleansing of Persons Act, 1897, to Ireland, the term Sanitary Authority is as defined under the Public Health (Ireland) Acts, 1878 to 1896. Any expenses incurred in the execution of the Act are to be considered as expenses in the execution of the said Public Health Acts, except in the case of rural authorities, where they must be deemed as general expenses. No Sanitary Authority can purchase or erect buildings for the purpose of this Act without the consent of the Local Government Board for Ireland.

CONTROL OF MIDWIVES.

By the Midwives Act, 1902, important duties bearing indirectly on the public health have been imposed upon certain Sanitary Authorities in England and Wales, including London. Every council of a county or county borough is, by this Act, constituted the local supervising authority over midwives within the area of the said county or county borough, and their duties or the duties of such District Councils to which the County Councils may, under section 9 of the Act, delegate their powers, are defined in rules drawn up by the Central Midwives Board under section 3. In addition to the registration of midwives, the following duties arise, namely, (1) to exercise a general supervision over all midwives practising within their area; (2) to investigate charges of malpractices, negligence, or misconduct on the part of a midwife: if a *primâ facie* case be established, it is to be reported to the Central Board; (3) to suspend a midwife from practice, when necessary, in accordance with the Midwives Board rules. The rules in question include the following:—

Whenever a midwife has been in attendance upon a patient suffering from puerperal fever, or from any other illness supposed to be infectious, she must disinfect herself and all her instruments and other appliances, to the satisfaction of the Sanitary Authority, and must have her clothing thoroughly disinfected before going to another labour. Unless otherwise directed by the local supervising authority, all washable clothing should be boiled, and other clothing should be stoved (by the Sanitary Authority), and then exposed to the open air for several days. Formal notification must be made by the midwife to the local supervising authority when any of the following occur:—(*a*) When the mother or the child dies without having been seen by a registered medical practitioner. (*b*) When the child is deemed to be still-born. (*c*) When, owing to the occurrence of various complications either of the labour or its after course, as defined in the rules, it has been necessary for the midwife to advise that a registered medical practitioner be sent for.

The local supervising authority must secure proper inspection of every midwife's case book, bag of instruments, and appliances, &c., and must, when necessary, make arrangements for the inspection of her residence, and for investigation of her mode of practice. The same authority is to suspend from practice a midwife who contravenes the directions issued for the use of disinfectants and for the proper safeguards against the spread of infection laid down by the Central Board, or other rules of the Board. Any inspection (with the reasons thereof) must be reported to the Central Board.

EMPLOYMENT OF YOUNG PERSONS IN SHOPS.

By the Shop Hours Acts, 1892, 1893, and 1895, which apply to Great Britain and Ireland, no young person shall be employed, with the knowledge of the employer, in or about a shop for a longer period than seventy-four hours, including meal times, in any one week. In calculating the number of hours of such employment in a shop either for a day or a week, the number of hours a young person has been employed previously in any factory or workshop under the Factory and Workshops Act, 1901, must be included. In every shop in which a young person is employed, a notice shall be kept exhibited by the employer in a conspicuous place referring to the provisions of these Acts, and stating the number of hours in the week during which a young person may be lawfully employed in that shop (section 4, Act of 1892). The penalty for employing persons contrary to the Shop Hours Acts is £1 for each person so employed. Section 8 of the Act of 1892 empowers Sanitary Authorities to appoint inspectors to execute the Act. These inspectors have the same powers as inspectors under sections 68 and 70 of the Factories and Workshops Acts, 1901, and it is their duty to see that the notice required by section 4 of the 1892 Act is kept exhibited in a conspicuous place and that no young person is employed beyond the statutory seventy-four hours per week. The Acts of 1893 and 1895 are merely short amending Acts. The expression " young person " means a person under eighteen years of age; and " shop " means retail and wholesale shops, markets, stalls, and warehouses in which assistants are employed for hire, and includes licensed public-houses and refreshment houses of any kind. Other terms have the same meanings as in the Factories and Workshops Act, 1901.

PROTECTION OF INFANT LIFE.

By the Infant Life Protection Act, 1897, it is required that persons receiving for hire infants for the purpose of maintenance must give notice to the local authority (in London this is the County Council, elsewhere the Board of Guardians, except in Scotland, where it is the Parish Council), furnish particulars and submit to inspection and supervision. The local authority may, by order, require the removal of such infant to a workhouse or " place of safety," if it be kept in premises which are so unfit or so overcrowded as to endanger its health, or if it be kept by persons unfit to care for it, or who, by negligence, ignorance or other cause, endanger its health.

EMPLOYMENT OF CHILDREN.

Under the Employment of Children Act, 1903, urban Sanitary Authorities with a population over 20,000 (or, in the case of Boroughs over 10,000, and elsewhere County Councils) may make bye-laws regulating the employment of children under fourteen (not under the Factory or Mines Acts), and street trading by persons under sixteen; the Act forbids carrying of heavy weights or other injurious occupations, street trading by children under eleven, and work between 9 P.M. and 6 A.M. As regards children employed in mines, factories and workshops, these provisions are administered by Home Office Inspectors only.

Under the Prevention of Cruelty to Children Act, 1904, a Sanitary Authority is charged with the duty of seeing to the observance of the conditions of licences granted by a Court for the employment of children over ten in public entertainments.

CHAPTER II

WATER

THE supply of wholesome water in sufficient quantity is a fundamental sanitary necessity. Without it injury to health inevitably arises, either simply from deficiency of quantity, or more frequently from the presence of impurities. In all sanitary investigations, the question of the water-supply is one of the first points of inquiry, and the evidence is overwhelming as to the frequency with which diseases are introduced by the agency of water. Apart from this, there are many industries that cannot be carried on without the use of tolerably pure and soft water, moreover it has also been found to be the most effectual and economic agent in the removal from our habitations of waste slops and sewage; but paramount to all these is the value of the sanitary results growing out of the maintenance of health and the inducement to cleanliness of person and habitation by the supply of an abundance of water delivered constantly to the householder.

PROPERTIES OF WATER.

Water, long believed to be an element or simple substance, is now known to be a chemical compound, consisting of two volumes of hydrogen and one volume of oxygen, and is formed whenever hydrogen gas or a combustible substance containing hydrogen is burnt in oxygen or atmospheric air. At the ordinary temperature of the air it is a clear, transparent, tasteless, and odourless liquid; it appears colourless when seen in small quantities, but that it has a pale blue colour is apparent when a white object is viewed through a column about two feet in depth.

At the temperature of 0° C. (32° F.) water becomes solid or freezes; during the act of freezing it expands nearly $\frac{1}{11}$th of its volume, a fact which explains the reason why, during frosts, frozen pipes split or burst, and why damp soils and rocks tend to crack during frost. This disintegrating action of water upon rocks and soils is due to the expansive force exerted by water when it solidifies, and the ice formed is practically incompressible—hence the hardest rocks are split and broken up. This solid water or ice has a specific gravity of 0·9168 when compared with water at the same temperature, consequently ice always floats on the surface of the water, and, since the density of water is greatest at 4° C. (39°·2 F.), it follows that, when part of it is cooled below that point, the colder portion remains at the surface, and when it reaches the freezing-point, is then converted into ice, while the water just below remains a few degrees warmer, being protected by the crust of ice from the cooling currents of the air.

The following figures express the essential facts regarding the weights of certain volumes of water in terms of common weights and measures. At 4° C. a cubic centimetre of water weighs one gramme or 15·432 grains. At 60° F., a cubic inch of water equals 16·386 cubic centimetres; one gallon

weighs 10 pounds and is the equivalent of 4543·5 cubic centimetres; while one cubic foot of water measures 6·23 gallons and weighs 62·35 pounds or 28·315 kilogrammes.

Water possesses a certain amount of elasticity and compressibility. Thus by increasing the pressure by the weight of 200 atmospheres its volume is said to be reduced $\frac{1}{12}$th. This compressibility of water increases as the temperature rises. Water has a high capacity for heat, and its specific heat is taken as the standard of unity in reference to which the capacities of other substances for heat are expressed; on the other hand, it is a very bad conductor of heat. Water evaporates at all temperatures even when in contact with atmospheric air or other gas, and the vapour given off has a density and tension determined by the temperature.

Under the ordinary atmospheric pressure—760 mm. (29·922 inches)—water boils at the temperature of 100° C. (212° F.) and is converted into more than 1600 times its own volume of gas (steam). If the pressure be reduced to nearly that of a vacuum the boiling-point is lowered to nearly 0° C. (32° F.), but if the pressure be increased, then the temperature of the boiling-point is raised; thus, at two atmospheres the boiling-point is 121°·4 C., at three atmospheres it is 135° C., at four atmospheres it is 145°·4 C., at five atmospheres it is 153° C., at ten atmospheres it is 181°·6 C., and at twenty atmospheres it is 214°·7 C.

Water has a remarkable power of dissolving substances, and is the most universal known solvent. It dissolves or retains all the known gases, and there are only a few solid substances that do not gradually yield to the solvent action of water, assisted as this is by the gases present in all natural waters. The solubility of different substances is, however, very unequal. Generally, the solubility of any particular body is increased in proportion as the temperature is raised, but there are exceptions to this rule; for example, water at 0° C. dissolves nearly twice as much lime as water at 100° C. In the case of gases, the amount which water can dissolve is largely dependent upon the pressure; and under ordinary pressure it is generally larger in proportion as the temperature is lower.

The aqueous solutions of solid substances and of certain liquids and gases have a higher density than ordinary water. The freezing-point of water-solutions is lower than that of water; thus sea-water, which is largely a solution of various salts of magnesium, sodium, and potassium, freezes less readily than fresh water. The boiling-point of water is raised when it contains solid substances in solution.

ON THE QUANTITY AND SUPPLY OF WATER.

In estimating the quantity of water required daily for each person, it is necessary to allow a liberal supply. There should be economy and avoidance of waste; but still, any error in supply had far better be on the side of excess. Many persons, either from the difficulty of obtaining water, or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. It is almost impossible to give a definition of cleanliness; nor perhaps is it necessary, since there is a general understanding of what is meant.

It must be clearly understood for what purposes water is supplied. It may be required for drinking, cooking, and ablution of persons, clothes,

utensils, or houses; for cleansing of closets, sewers, and streets; for the drinking and washing of animals, washing of carriages and stables; for trade purposes; for extinguishing fires; for public fountains or baths, &c. It follows that the quantities necessary for different communities must vary a good deal, according as men live together in towns or are scattered in rural districts, and according as there may be or may not be systems of drainage or trades and manufactures.

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem. The following are the gross amounts used in some typical communities, for all purposes, in gallons per day:—London 35, Liverpool, 31, Manchester 29, Edinburgh 38, Glasgow 58, Sheffield 25, Leeds 34, Bristol 22, Swansea 36, and Leicester 17. The disparity between some of these figures is certainly remarkable. The gross amount thus taken is used for different purposes; these may be considered in detail.

Amount required for Domestic Purposes.—For drinking purposes the amount varies with age, sex, weight, climate, and occupation; but it may be laid down as a rule that the total daily amount necessary is equal to about half an ounce for each pound weight of the body, or, in other words, an adult takes in daily about 70 to 100 ounces ($3\frac{1}{2}$ to 5 pints) of water for nutrition. Now of this water about one-fourth to one-third exists in the so-called solid food, that is, in the meat, bread, &c., and the remainder is taken in some form of liquid. There are, however, wide ranges from the average. Women drink rather less than men; children drink, of course, absolutely less, but more in proportion to their bulk than adults.

For the cooking of food a certain amount is required, only part of which is actually consumed with the food. This will generally not be less in the case of adults than three-quarters of a gallon daily. Taking all sexes and all ages together, we may lay down the minimum necessary for drinking and cooking purposes as 1 gallon per head per diem.

For ordinary personal washing it is permissible to reckon that 3 gallons will be needed, while for the washing of clothes, utensils and general house-cleaning another 3 gallons will be required daily for each person. We may say, therefore, that for personal and domestic use, without baths and water-closets, 7 gallons per head daily will be the usual minimum supply, while with baths quite 11 gallons should be allowed. This makes no allowance for water-closets or for unavoidable waste. If from want of supply the amount of water must be limited, 4 gallons daily per head for adults is probably the least amount which ought to be used, and in this case there could not be daily washing of the whole body and there must be insufficient change of under-clothing. While in Glasgow 37 gallons daily are used for domestic needs, in Hull the figure is 26 gallons, in Leicester 11·7 gallons, and in Sheffield but 10·5 gallons. We can only explain these discrepancies on the assumption that there must be preventable waste somewhere.

Amount required for Water-closets.—These sanitary conveniences cause, undoubtedly, a considerable waste of water, but with the present-day use of "waste-preventer" cisterns it is reduced to a probable minimum. The usual quantity available for each flushing varies from 2 to 3 gallons, but, as a rule, should not fall below the latter amount. Allowing that each person, on an average, uses the closet twice daily, from 5 to 6 gallons should be provided for this purpose. The same quantity may be said to be needed daily for water-latrines. In addition to the above it may be advisable to allow each person daily some 3 gallons for what is called

unavoidable waste. This will make, where fixed baths and water-closets are in use, an average need per head for house-supply of 20 gallons.

Amount required for Animals.—This is difficult to estimate definitely, as where animals are in use there is a corresponding need of water for washing carts and carriages. Horses, mules and oxen will consume 5 gallons of water daily as drink; if to this we add some 3 gallons daily in each case for carriage washing and cleaning, we find the daily need of horses, mules, oxen and other animals in ordinary use to average at least 8 gallons each; and, taking one case with another, this is not an excessive estimate. As it is not every person who keeps animals, the daily allowance under this head on the general population may be put at 3 gallons for each person.

Amount required for Municipal and Trade Purposes.—Under this head, water is taken for washing and watering streets, for fountains, public baths, and for extinguishing fires, &c. The amount needed for these and trade purposes varies greatly, but, taking one town with another, it may be put at 9 gallons daily for each inhabitant.

Summarising, the total daily amount of water needed for all purposes may be stated to be, per head of population, as follows:—

	Gallons.
Domestic supply (without baths or closets)	7
Add for general baths	4
„ water-closets	6
„ unavoidable waste	3
Total, house-supply	20
Town and Trade purposes (including animals)	12
Total, domestic and municipal needs	32

In India and hot countries generally, the amounts now laid down would probably suffice. Although more must be allowed for bathing and washing generally in these places, the absence of a system of water-carriage sewerage involves a corresponding saving under the head of water-closets and municipal requirements.

Amount required for Hospitals.—In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are approximately the daily requirements of most institutions of this kind.

There is no doubt that an enormous quantity of water is wasted both in private houses and public buildings, and economy might be effected without any detriment to sanitary requirements. The case of Leicester is an encouraging example of how economy can be secured: only 5·5 gallons are used daily for trade purposes, and 11·7 gallons for domestic needs. These results have been obtained by the work of waste inspectors, and the strict examination, testing and stamping of all water-fittings. What can be done in one place can be done in another; this is a matter which demands the interest of the individual citizen as much as it concerns those acting as corporate bodies.

SOURCES OF WATER-SUPPLY.

The constant evaporation which takes place from the surface of all masses of water exposed to the atmosphere, the diffusion of water-vapour throughout the atmosphere, and its subsequent condensation there to the liquid or solid state, give rise to the incessant circulation of water which

is continually taking place. Of this condensed atmospheric vapour, falling on the surface of the various continents and islands, part penetrates into the soil until it reaches a less permeable stratum, above which it accumulates; part flows away and becomes the source of the great rivers and lakes, some is absorbed by the soil itself, while the remainder passes off in vapour to be again condensed in the form of either rain, snow, hail, dew or mist. Viewed in this manner, this condensed water from the atmosphere is the primary source of all our water-supplies. These again resolve themselves practically into either (1) rain, pure and simple; (2) water derived from melted snow or ice; (3) water collected on the surface of the ground in the form of ponds, lakes (upland surface water), streams or rivers; (4) so-called ground water or that which has percolated to varying depths into the soil and reaching the surface again either by means of springs or wells. Supplementary to these four chief sources of drinking-water may be mentioned sea-water and distilled water. Each class of supply has its own peculiar characteristics and demands special consideration.

Rain-water approaches nearer to absolute purity than any other kind of natural water. When collected in clean vessels it contains only such dissolved substances as it can take up from the atmosphere. As it falls through the air it becomes highly aërated, the amount of contained gas averaging 25 c.c. per litre, of which about 34 per cent. is oxygen, 64 per cent. is nitrogen, and 2 per cent. carbon dioxide. In addition, ammonia is usually present, and any suspended matters which may be floating in the air, so that before rain reaches any collecting-surfaces it may have added to it as much as two grains of solid matter in a gallon of water. In inland districts, especially where large manufacturing works are carried on, these impurities may be increased by the addition of various sulphur compounds and other products of coal combustion.

It will be thus seen that, even before it reaches any collecting-surface, rain-water varies much in composition, and that the amount of its impurity, both mineral and organic, may be occasionally large. It is, however, mainly from the surfaces on which rain falls that the chief impurities result; these consist generally of bird-droppings, decayed leaves, soot and such matters as collect on roofs, platforms, gutters and receiving-vessels. For these reasons, rain-water, as ordinarily collected and met with, is an impure and dirty water, and its use as a supply for drinking purposes only justified in places where no better source is available. The chief merit of rain-water is its softness, owing to the absence of salts of lime and magnesia; on this account it is good for washing or cooking purposes, although this very attribute of softness renders it less palatable than other kinds of water for drinking. Owing to its aëration and richness in dissolved air, rain-water has frequently a considerable erosive action on lead; this is a feature of some importance in connection with pipes, fittings and cisterns, or tanks to be used for its storage.

Apart from these drawbacks, rain as a general source of water-supply for domestic purposes is unsatisfactory, owing to the uncertainty of the rainfall from year to year, the length of the dry season in many countries, and the large size of the reservoirs which are then required.

The *amount* of water given by rain can be easily calculated if two points are known, viz., the amount of rainfall and the area of the receiving-surface. The rainfall can only be determined by a rain-gauge, the area of the receiving-surface must be measured.

The following formula is the one generally used:—

$$\frac{\text{Area in square feet} \times 144 \times \text{rainfall in inches}}{1728} = \text{cubic feet.}$$

To calculate the receiving-surface of the roof of a house, we must not take into account the slope of the roof, but merely ascertain the area of the flat space actually covered by the roof. The joint areas of the ground-floor rooms will be something less than the area of the roof, which also covers the thickness of the walls and the eaves.

In most English towns the amount of roof-space for each person cannot be estimated higher than 60 square feet, and in some poor districts is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving-surface for each person would give 935 gallons, or $2\frac{1}{2}$ gallons a day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water-butts. If, instead of the roof of a house, the receiving-surface be a piece of land, the amount may be calculated in the same way. It must be understood, however, that this is the total amount reaching the ground ; all of this will not be available ; some will sink into the ground, and some will evaporate ; the quantity lost in this way will vary with the soil and the season from one-half to seven-eighths.

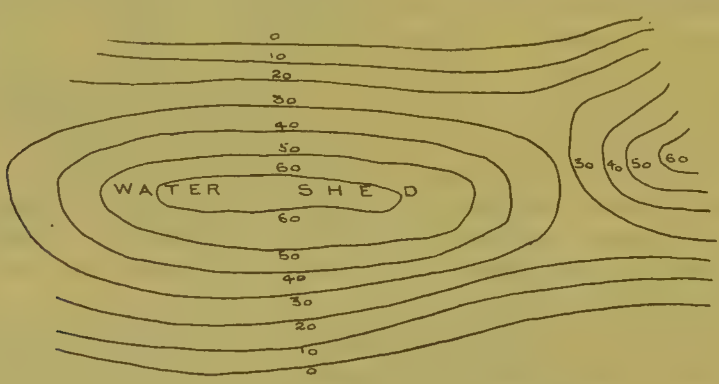


Fig. 1.—Contour Lines, showing Watershed.

One inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each acre. Inches of rainfall $14\frac{1}{2}$ = millions of gallons per square mile.

The extent and value of any given tract of country as a catchment area for water can be determined only by a study of properly prepared maps. The ordnance maps of this country include general maps on a scale of an inch to a mile, county plans on a scale of six inches to a mile, and parish plans on a scale of twenty-five inches to the mile. Surface levels are shown along roads on the six- and twenty-five-inch plans. Contours, as shown by altitude, are indicated at 100 feet intervals on the one- and six-inch maps up to 1000 feet above ordnance datum, but in some flat districts the 25-feet contour is shown, while for ground at greater elevation than 1000 feet the interval varies from 100 to 250 feet. The importance of the contour lines in the map of any given district as indicating its value as a watershed or catchment area will be manifest, as these lines separate drainage areas and form therefore the boundary of catchment basins. The boundaries of a given gathering-ground being determined, its area can be ascertained by the use of a map drawn accurately to scale.

In estimating the annual yield of water from rainfall, and the yield at any one time, we ought to know the greatest annual rainfall, the least, the average, the period of the year when it falls, and the length of the rainless season. Hawksley states that the average of twenty years, *less* one-third,

gives very accurately the amount of rain in the driest year, and the same average, *plus* one-third, gives very nearly the amount in the wettest year. The average of the three driest years in twenty is a safe basis.

It may be assumed that on the average $\frac{6}{10}$ths of the rainfall is available for storage. It must also be remembered that the amount of rainfall differs very greatly even in places near together.

The utility of **Ice- and Snow-water** is obviously very limited; moreover, its use is not free from danger, especially in the case of ice derived from polluted water. The mere act of freezing appears to have a relatively feeble effect in destroying bacteria, and on this account, because water has been frozen, it cannot be deemed necessarily safe. In its general qualities, water derived from dew or melted snow may be regarded as similar to ordinary rain.

Upland Surface-water, being the water collected in hilly districts, as on moorlands, presents many of the qualities of rain-water. It contains usually more dissolved solids, their amount and nature depending on the kind of soil over which the water rests, and consequently it is usual to subdivide this class according to the geological character of the ground from which the upland surface-water is obtained. These waters do not contain any considerable amount of dissolved matters, unless they are derived from calcareous strata ; the organic substances present are chiefly of vegetable and not of animal origin. There is also an absence of ammonia, nitrates, and nitrites beyond that which occurs in rain-water. The chlorine is also low and the water soft. These upland surface-waters are not only valued because of their safety for drinking, but also on account of their fitness for trade purposes, although occasionally they display an ability to both erode and dissolve lead when in contact with that metal. Several large towns in recent years have provided themselves with water collected upon upland areas, either utilising existent lakes or making artificial reservoirs in hilly districts by constructing dams of masonry across valleys.

Spring- and Well-water.—The rain falling on the ground partly evaporates, partly runs off, and partly sinks in. The relative amounts vary with the configuration and density of the ground, and with the circumstances impeding or favouring evaporation, such as temperature, movement of air, &c.

Penetrating into the ground, the water absorbs a large proportion of carbonic acid from the air in the interstices of the soil, which is much richer in carbon dioxide than the air above. It then passes more or less deeply into the earth, and dissolves whatever can be taken up in the time, at the temperature, and by the aid of carbonic acid. In some sandy soils there is a deficiency of carbon dioxide and then the water is also wanting in this gas, and is not fresh and sparkling.

The chemical changes and decompositions which occur in the soil by the action of carbon dioxide, and which are probably influenced by diffusion, and perhaps by pressure, as well as by temperature, are extremely curious, but cannot be entered upon here. The most common and simple are the solution of calcium carbonate, and the decomposition of calcium and sodium silicate by carbonic acid or alkaline carbonates.

Springs are of three kinds—land springs, main springs, and intermittent springs.

Land springs are derived from the percolation of water through superficial porous soils, such as sand, gravel, or alluvial earth overlying impervious strata. The yield of water is uncertain, depending on the available porous collecting area, which may be of small extent. When adopting a land

spring as a source of supply, it must be gauged several times in the year, especially in summer and autumn.

Main springs are deep-seated springs whose source is the water percolating through thick masses of porous soil overlying an impervious stratum ; often the collecting-area is some distance from the spring. These springs are chiefly found in the chalk and greensand.

Intermittent springs or bournes are usually found in valleys traversed by rivers and bounded on one side by hills. The underground water rises from the river level to the hills, and in winter the rise is much steeper than in summer ; the water-level may then reach the surface at a certain spot on the side of the hill instead of remaining beneath the impervious strata. The spring will disappear in summer as the level of the underground water falls again, and in this way an intermittent spring will be produced.

Spring-water is almost always clear and bright, in consequence of the great degree of filtration which it naturally undergoes in percolating through the strata which it may have traversed between the gathering-ground from which it has penetrated and the point at which it issues again from the earth. For the same reason it is generally cool, and by reason of the gas it contains, it is sparkling and brisk to the taste. The temperature of the water varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season ; that of deeper springs is often that of the yearly mean. In very deep springs, the temperature of the water may be occasionally high.

Wells are of different kinds—shallow wells, deep wells, and Artesian wells.

A well of 50 feet in depth, or less, is generally regarded as a shallow well; one of 100 feet or more as a deep well. Artesian wells are generally of great depth, passing through an upper impermeable stratum, *e.g.*, clay, and penetrating a water-bearing stratum, which crops up elsewhere at some higher point, and below which is another impermeable stratum. Ordinary wells are sometimes supplemented by borings to increase the supply.

Shallow wells may be contaminated with any impurities at or near the surface of the ground, and the water from such wells is always to be regarded with suspicion. Even when the organic matter is only small in amount, it is generally highly nitrogenous, pointing to its probable animal origin, and in some exceptional cases the organic nitrogen found is actually in excess of the carbon. Deep wells are generally good sources of supply. The great efficiency of the filtration which most of these deep-well waters have undergone is attested by their entire freedom from organic matter, and by their almost absolute freedom from every kind of suspended material whether organic or inorganic. Deep-well waters, as regards organic matter, are amongst the purest to be found in nature, and unless extremely hard, they are of the best for drinking purposes.

In shallow wells, say from 10 to 50 feet deep, the soakage water from the ground in loose soils is often very impure. In or near towns, villages, or farmyards this pollution is very liable to occur, the whole of the subsoil water over an extended area becoming polluted. Occasionally, by constant passage of the water, a channel may be formed, which may discharge suddenly into the well ; probably some of the cases of sudden infection from water have thus arisen, particularly in chalk formations, where the existence of fissures is not infrequent. A striking instance of this kind, showing the extent to which contaminating materials may be diffused to even distant wells, was the demonstration of the possible fouling of the sources of the Cambridge

water-supply at Cherry Hinton and Fulbourn by percolation of material from the sewage-farm of the neighbouring asylum.*

A well drains an extent of ground about it nearly in the shape of an inverted cone. The area must depend on the nature and porosity of the soil, but in the majority of cases the radius of the area drained is equal to four times the depth at least, and may even exceed this. Observations show that the curve of the subterranean water-level rises suddenly near a well and becomes flatter and flatter as it extends under the ground-surface, the distance to which it reaches depending upon the lowering of the level of water in the well. Thus a shallow well heavily pumped may drain an area wider than a deeper well under moderate pumping. The distance to which the influence of pumping extends is very variable, ranging from 15 to 160 times the depression of the water in the well. It is this depression of water in the well, that is, the quantity of water taken out, that determines the drainage area, rather than the mere depth of the well.

A well which yields a moderate quantity of good water may, if the demand on it be increased, draw in water from the surrounding parts to meet the supply, and thus tap sources of impurity which a moderate demand left untouched. A sudden rise in the ground-water may also lead to direct communication between a cesspool and a well, by the water tapping the former in its flow.

In some cases a well at a lower level may receive the drainage of surrounding hills flowing down to it from great distances. Good coping-stones, so as to protect from surface washings, and good masonry for several feet below the surface of wells in very loose soils, so as to prevent superficial soakage, are necessary in all shallow wells. In the majority of cases where shallow wells yield polluted water, this is due to defects in their construction. The accompanying figure (Fig. 2) indicates a simple plan for the construction of such wells, and constitutes a type which it is desirable that builders and others should follow. The growth of trees should not be encouraged in the immediate vicinity of wells, as their roots are apt to cause facilities for the inlet of surface-water; for similar reasons moles and rats should be prevented from burrowing near wells.

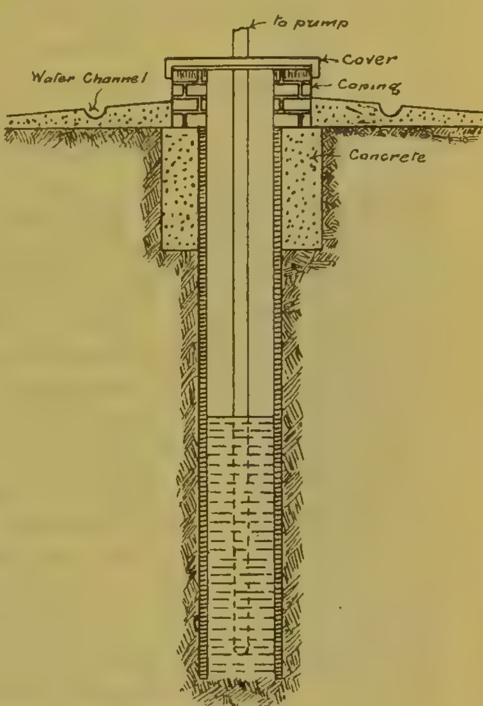


Fig. 2.—Well, suitably protected.

Tube-wells, commonly known as Norton's Abyssinian tube-wells, are used when a temporary supply is required: they are superior to dug wells, which, from imperfect steining or total absence of it, are liable to become foul from surface pollution. They are constructed by driving tubes into the soil, one length being screwed on to another, the first tube being perforated at the bottom for about 2 feet, its lower end being furnished with a steel point (Fig. 3).

When the subsoil water is reached, a pump is attached to the tube; the

* Dr. S. Monckton Copeman's Report to the Local Government Board on an outbreak of Enteric Fever at Fulbourn Asylum, near Cambridge, February 1906.

water, after pumping a short time, is clear ; the tube forms a cavity which corresponds to the ordinary well at the end of the pipe, owing to the removal of the soil by pumping. Koch recommends that iron tubes be placed in dug wells, and the surrounding space filled in with clean gravel and sand, the water to be raised by a pump fixed at the surface.

River-water.—Fed from a variety of sources, river-water is even more complex in its constitution than spring-water ; it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, &c. The water taken on opposite sides of the same river has been found to differ slightly in composition.

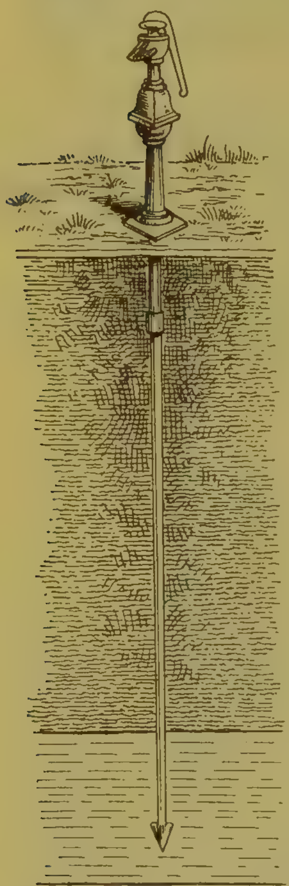


Fig. 3.—Tube Well.

The dissolved solids in river-water vary less than in spring-water : they rarely exceed 30 to 40 parts per 100,000. Sometimes the water is almost as pure as rain-water. The amount of dissolved organic substances is generally much greater than in spring-water. This is due to the surface-drainage being discharged into the rivers. River-water is generally good and palatable, unless sewage or other impurities are allowed to pass into it.

The general result of solution and decomposition is, that the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking, except as medicines. The impurities of water are not so much influenced by the depth of the source as by the strata it passes through. The water of a surface spring, or of the deepest Artesian well, may be pure or impure.

The substances which are contained in spring-, river-, and well-waters are noted more fully under the head of "Examination of Water." These may be suspended matters, mineral, vegetable, or animal ; dissolved gases, viz., nitrogen, oxygen, carbon dioxide, and in some cases hydrogen sulphide and carburetted hydrogen ; and dissolved solid matters, consisting of lime, magnesia, soda, potash, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. Less frequently, or in special cases, certain metals, as arsenic, manganese, lead, zinc, and copper, may be present. The mode of combination of these substances is as yet uncertain ; it may be that the acids and bases are equally distributed among each other, or some other modes of combination may occur. The mode of combination may *usually* be assumed to be as follows :—the chlorine is combined with sodium, and if there is an excess it is combined with potassium or calcium ; if there is an excess of sodium, this is combined with sulphuric acid, or if still in excess, with carbonic acid. Lime is combined with excess of chlorine, or sulphuric acid, or if there be no sulphuric acid, or an excess of lime, with carbonic acid. Magnesia is combined with carbonic acid. So that the most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate.

Distilled Water.—Distilled water is now largely used, distillation being one of the most effectual modes of freeing water from all its impurities. On board ships distillation of sea-water is resorted to in order to render salt water fit for drinking, and although the water thus obtained is pure, yet all the gases having been driven from it by the boiling, it is unpalatable and, by some supposed to be, indigestible. It may be aërated by allowing it to trickle slowly down through a long column of wood charcoal, or by filtration through animal charcoal or other porous substance. Distilled water is also employed for the manufacture of aërated waters, and for artificial ice.

Care should be taken that no lead, zinc, or copper finds its way into the distilled water. Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition. If possible *block tin* should always be used.

Sea-water.—While the ocean is constantly receiving waters more or less impure, it is at the same time losing pure water in the form of vapour, the mineral salts remaining behind, and imparting to it its saline character.

The composition of sea-water varies considerably in different places and at different depths. Thus, in the vicinity of the poles the proportion of salt is less than at the equator, while parts of the Mediterranean are more salt than the great oceans.

Comparative Value of the Various Sources of Water-supply.—This depends on many circumstances. Spring-water is both pure and impure in different cases; and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Much depends upon the geological formation and how well the spring is protected from surface pollution. When springs arise from sand or gravel, the immediate neighbourhood needs careful scrutiny; as a rule, from five to ten acres above and around a spring should be free from all manurial matter, and that portion of the area immediately affecting the spring should be enclosed to prevent the access of men and cattle. If heavy rainfall renders a spring water turbid, it is highly suggestive that the source is unsatisfactory. Shallow-well water is always to be viewed with suspicion; the same must be said of most river-water, as a river is the natural point to which the drainage of a good deal of surrounding land tends, and heavy rains will often wash many substances into it. Apart from this, few rivers are free from the discharge into them of much objectionable matter, if not actual sewage. Upland surface-waters are, as a rule, safe, but much depends upon the presence or absence of habitations, flocks or herds of animals, and adequate policing of the collecting-area.

Classification of Drinking Waters.—The general characters of good water are easily enumerated. Perfect clearness; freedom from odour or taste; coolness; good aëration; and a certain degree of softness, so that cooking operations, and especially of vegetables, can be properly performed, are obvious properties. But when we attempt a more complete description, and assign the amounts of the dissolved matters which it is desirable should not be exceeded, we find considerable difference of opinion, and also a real want of evidence on which to base a satisfactory judgment.

The following tables are given by the Rivers Pollution Commissioners:—

I. In respect of wholesomeness, palatability, and general fitness for drinking and cooking:—

Wholesome	1. Spring-water . .	very palatable.
	2. Deep-well water .	
	3. Upland surface-water .	moderately palatable.
Suspicious	4. Stored rain-water .	
	5. Surface water-from cultivated land . . .	palatable.
Dangerous	6. River-water, to which sewage gains access . .	
	7. Shallow-well water	

2. Classified according to softness with regard to washing, &c. :—

1. Rain-water. 2. Upland surface-water. 3. Surface-water from cultivated land. 4. Polluted river-waters. 5. Spring-water. 6. Deep-well water. 7. Shallow-well water.

STORAGE AND DELIVERY.

The methods of storing and delivering water will vary with its source. In upland surface schemes, storage reservoirs are a necessity to equalise the supply and demand ; they are usually made by impounding the water from the gathering-grounds in such a position that the town or community may be supplied by gravitation. Compensating and service reservoirs are also necessary : the former to receive the turbid water at flood time, so that the compensation water to be given to streams and mills shall not be a tax on the clear-water reservoir ; the latter to receive the clear water, and directly supply the town. The storage which is required in the impounding reservoir is given by Hawksley's formula $D = \frac{1000}{\sqrt{F}}$, F being the mean annual rainfall in inches of three consecutive dry years, say $\frac{5}{6}$ths of the average annual rainfall, and D the number of days' storage. It is usually from four to six months' supply. The most common way of forming storage reservoirs is that in which a dam is thrown across a valley. The best site is the one where the smallest dam is required with comparative uniformity of depth in the reservoir, so that there may be no undue proportion of shallow water where the growth of vegetation will be fostered. The geological features of the region must be carefully examined so that the reservoir may be watertight. Earthwork is chiefly used to form large dams, and in England a wall of puddled clay is placed in the centre of the dam and carried down in a trench so as to form a watertight junction with an impervious stratum. The outlet culvert from the reservoir must be bedded in concrete on the solid bottom of the trench ; generally the culvert discharges into a basin or open conduit. The apparatus, viz., valves, sluices, &c., for regulating the discharge of water, is usually placed at the inner end of the outlet. A waste-weir and bye-wash are also necessary, so as to permit the discharge of water in times of flood.

It is generally advisable to have works at the upper end of the reservoir so as to regulate the admission of water, and entirely divert it if necessary during times of flood. From the impounding reservoir the water is carried by an aqueduct, either closed or open, to the service reservoir, which is usually covered and made so as to hold from twelve hours' to two days' supply. Large towns are divided into districts, each of which has a service reservoir. Upland surface supplies are not usually filtered, but if there is any chance of pollution of the water from habitations on the catchment-area, filtration must be employed.

When water is obtained from a river the intake should be placed where a good stream is constantly flowing ; stagnant and shallow parts must be avoided. The water is best taken 5 feet below the lowest summer level, screens being placed so as to exclude grosser suspended materials. In river

schemes it is usually deemed unnecessary to provide the large storage reservoirs required to equalise the supply and demand in gravitation schemes. It is sufficient if the smallest dry-weather flow of the river is so large as not to be seriously affected by the withdrawal of the amount required for the works. The water required is generally led from the river into subsiding reservoirs, where a considerable amount of purification takes place; but even after sedimentation a river-water cannot be used for drinking purposes, it must be purified by sand filtration. The areas of subsiding reservoirs vary greatly, due to differences of opinion as to the most economical point to carry the clarification before commencing filtration, but experience shows that, the larger the storage reservoirs and the longer the water can be retained in them, the greater is the self-purification obtained. The recent extension in area of storage reservoirs in the vicinity of London has resulted in a material improvement in the quality of the water supplied, particularly in that derived from the Thames and Lea. Depositing or subsiding reservoirs are usually made equal to three days' demand, and generally from 10 to 15 feet deep. From the depositing reservoirs the water is passed on to the filter-beds; the filtrate is then collected in clear-water wells, from whence it is pumped up to service reservoirs so as to obtain the necessary head to supply the various districts.

At one time deep wells were a common source of supply for towns. Borings made into the chalk and New Red Sandstone yielded an excellent water, which was pumped up into large tanks placed at the top of a water-tower, so as to obtain the necessary head. In some cases, however, it was found extremely difficult to meet the requirements of steadily growing towns; borings could not be increased indefinitely as each one drained a considerable area, and wells sunk in gravel-beds were liable to be influenced by seasons of drought. For these reasons wells are now being given up for the supply of large towns, but are still retained for small communities, such as prisons, asylums, &c.

In villages and rural districts, shallow wells often form the only source of supply; they are usually open to pollution, and should be looked upon with suspicion unless covered, steined to a sufficient depth, and surrounded by at least an acre of unpolluted ground.

Occasionally rain-water collected from the roofs of buildings is the only available source of supply; great care should then be taken to ensure its freedom from metallic compounds and organic impurities. Rain-water must never be collected from lead surfaces, and even roofs covered with sheet-zinc or galvanised iron give up zinc to water collected from them. After a drought the first water obtained contains many impurities. Roberts has devised a separator for getting rid of the impure water first collected. The separator contains a canter which, when empty, is heavier on the right side than on the left. The rain-water, first entering the separator, runs round the canter and passes out at an aperture placed behind the exit to the storage-cistern. But gradually a compartment on the left side of the canter fills with water, and at a certain point its weight is sufficient to overbalance the canter and so force the main column of water to run out at the storage-outlet. The amount of water delivered so as to overbalance the canter is arranged to have a definite relation to the area of the collecting-surface; when all the clean rain-water has passed through the separator the water in the canter is removed by siphon action, and the canter then falls back to its original position.

Rain-water intended for drinking purposes, after leaving the separator, should always be filtered through sand and stored in cisterns. The materials

of cisterns are stone, cement, brick, slate, tiles, lead, zinc, and iron. Of these, slate is the best, but it is rather liable to leakage, and must be set in good cement or in Spence's metal; common mortar must not be used for stone or cement, as lime is taken up and the water becomes hard. Leaden cisterns, as in the case of leaden pipes, often yield lead to water, and should not be used; they are corroded by mud or mortar, even when no lead is dissolved in the water. Iron cisterns and pipes are often rapidly eaten away; they are sometimes protected by being covered inside with Portland cement or with a vitreous glaze or with patent cement. Barff's process of producing the magnetic oxide on the surface of iron has been tried, but seems hardly so successful as it promised. Galvanised iron tanks are also very much used; they must be covered, and in India be protected from the sun. Zinc has been recommended, but water passing through zinc pipes, or kept in zinc pails, or in badly galvanised iron vessels, may produce symptoms of metallic poisoning, and even taste strongly of zinc salts, especially if the water is rich in nitrates. It would certainly be better to abandon lead, zinc, and such-like materials for cisterns, as much as possible, unless we are sure that the water contains no substance likely to act upon these metals.

Cisterns should always be well covered, protected as much as possible from both heat and light, and thoroughly ventilated if they are large. Care should always be taken that there is no chance of leakage into them. An occasional source of contamination is an overflow-pipe passing direct into a soil-pipe or drain, so that the sewer-gases pass up, and, being confined by the cover of the cistern, are absorbed by the water; to prevent this, the overflow-pipe is curved so as to retain a little water and form a trap, but the water often evaporates, or the gases force their way through it; no overflow-pipe should therefore open into a drain, but should end *above* ground over a trapped grating. A cistern supplying a water-closet should not be used to supply cooking and drinking water, as the pipes leading to the closet often conduct closet air to the cistern. Hence, a small cistern (water-waste preventer) should be used for each closet. Cisterns should be periodically and carefully inspected; and in every new building, if they are placed at the top of the house, convenient means of access should be provided. Tanks to hold rain-water require constant inspection.

Distribution.—When houses are removed from sources of water the supply should be by aqueducts and pipes. The distribution by hand is rude and objectionable, for it is impossible to supply the proper quantity, and the risks of contamination are increased.

The supply of water to houses may be on one of two systems, *intermittent* or *constant.* The difference between the two plans is, that in the first case there is storage in the houses for from one to three days; while in the latter case there is either no storage, or it is only on a very small scale for two purposes, viz., for water-closets and for the supply of kitchen boilers. It should, however, be understood that the constant supply has not always meant in practice an unlimited supply, nor has it been the case that the water in the house-pipes was always in direct communication with the water in the reservoirs. On the contrary, the water to the houses has often been cut off, particularly in places where the supply was limited, and the fittings not good, and where there was great waste. The weak point in the system of constant supply is the surrender of all control of the supply at times of drought, heat, or frost, when there is widespread waste or misuse of water, resulting sometimes in scarcity, in the less favourably situated localities.

The intermittent charging of pipes favours corrosion, which in turn

causes turbidity, while the shutting-off of the water from the service-mains and their depletion by the gravitation of the water into the basement cisterns or by leakage, tend to create a vacuum into which may be drawn either foul air or foul water. In case of fire a supply of water cannot be ensured without the intervention of a turncock. All the above evils are avoided by the use of a constant service.

The terms used to describe the pipes differ a little apparently; the mains and districts or sub-mains are the large pipes, which are always full of water, the latter being, of course, the smaller; the service-pipe is another term for a district main. The communication-pipe is that which runs from the service-pipe to the house, and in the house it takes the name of house-pipe.

The great arguments against storage on the premises (except on a limited scale for closets and boilers) are the chances of contamination in cisterns, and the very imperfect means of storage, which is especially the case in houses occupied by the working classes.

In providing a constant supply, certain precautions are necessary. The fittings must be as perfect as possible. When the fittings are good, there is real economy in the constant system, and given careful inspection with good fittings there need be no waste of water.

If the constant system is used, a good screw stopcock, available to the tenant, should be placed at the point of entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost. Every precaution must be taken that impure water is not drawn into the pipes by a pipe being emptied and sucking up water from a distance.

For the supply of a very large city, it might be desirable to divide the city into sections, and to establish a reservoir for each district, holding three or four days' supply. In this way the waste of one section would not take away the water from another. In some instances, people in one part of a town, supplied on the constant system, have used so much water for gardens that other parts have been altogether deprived of supply. The system of secondary reservoirs would not only lessen this chance, but would make it possible to be certain that every part of the town was getting its supply.

There is no doubt that the constant system is the safer, especially for poor houses, as it leaves no loophole for inattention in the cleansing of cisterns. Only, it requires that the constant system should really fulfil the conditions laid down for it—viz., it should deliver sufficient water at all times, and not merely delude us with a phrase.

In both plans the water is conducted from the reservoirs in pipes. The pipes are composed of iron, stoneware, or masonry, for the larger pipes or mains, cast iron being those most generally in use. The length of the pipes is usually about 9 feet, and a hub and spigot joint formed, adapted first to a joint packing of deal wedges and afterward to a packing of lead. This form of joint admits of their free expansion and contraction with varying temperatures of water and earth, and renders them less liable to fracture. For the smaller pipes, galvanised iron, lead, tin, vitreous glazed iron pipes, &c., are used.

The action of water upon iron pipes appears to be energetic at first, but diminishes after a little time. Several processes have been proposed for the preservation of the pipe surface. Barff's method consists in raising the temperature of the metal to about 1200° F. (a white heat) in a suitable chamber, into which is passed superheated steam; the metal is exposed

to this action for several hours, and becomes coated with a protective oxide. Angus Smith patented a process for coating iron pipes with a varnish of pitch, derived from coal tar; the pipes are heated in a retort or oven to a temperature of about 310° F. and then immersed in a bath of pitch which is maintained at a temperature of not less than 310° F. The pitch is specially prepared, being distilled from coal tar until the naphtha is entirely removed and the material deodorised; to this about 5 or 6 per cent. of linseed oil is added. The pipes should be free from rust and strictly clean when they are immersed in the pitch bath.

Sheet-iron water-pipes lined and coated with hydraulic cement are used in the United States. The sheet iron is formed into pipes about 8 feet long, and riveted. These are then lined with hydraulic cement, and when lined are enclosed in a bed of cement. Iron is the best material for the larger pipes, and it is also necessary (steam-piping) for the smaller pipes under the pressure of the constant service system.

Water should be distributed not only to every house, but to every floor in a house. If this is not done, if labour is scarce in the houses of poor people, the water is used several times; it becomes a question of labour and trouble *versus* cleanliness and health, and the latter too often give way. Means must also be devised for the speedy removal of dirty water from houses for the same reasons. In fact, houses let out in lodgings should be looked upon, not as single houses, but as a collection of dwellings, as they really are.

Action of Water on Lead Pipes.—The apparently inscrutable behaviour of certain waters, especially soft moorland waters, in regard to plumbo-solvent ability, may be said to be now understood. For this explanation we are indebted to the work of Houston on behalf of the Local Government Board.* Preliminary inquiry had shown that the plumbo-solvency of any water was associated with corresponding variations in the amount of acid in the water. This acidity is derived by contact of the water with the moist peat on moorland catchment areas, the actual formation of the acid being due to the presence of acid-producing bacteria in the peat itself. Houston's work indicates, further, that there is a difference in kind of action exercised by water on lead, some waters being plumbo-solvent and others plumbo-erosive. In one case the action (plumbo-solvency) is brought about by acidity of the water; in the other, the action (erosion) is an inherent property of water containing dissolved air. The erosive action, as distinguished from the true solvent action of acid waters, shows itself by the formation of a relatively insoluble compound or powder (oxyhydrate of lead), which may tend to fall away from the surface of the metal, and so permit of progressive action. Fortunately, however, erosion takes place only to any large extent when the lead is bright; and moreover most natural waters, particularly hard waters and those rich in free carbonic acid, contain ingredients which prohibit the action. Neutral distilled water erodes lead vigorously. Interesting as this phase of the subject is, it is quite secondary in practical importance to the question of plumbo-solvent ability, which is due to acid in the water derived from acid peat and formed by acid-producing bacteria in the peat itself.

The means that have been proposed to prevent injurious effects from lead gaining access to the system through the medium of drinking water are:—(1) to treat the water before it enters the pipes, so as to prevent its being capable of acting on the metal, should it come in contact with it; and (2) to

* Houston; Supp. in continuation of Rep. of Med. Officer Loc. Gov. Board for 1901–2.

use for distributing the water, pipes which will not allow of the water coming in contact with the lead. Thus, if the free acid present is neutralised by the addition of lime to the water, its solvent action on lead pipes is prevented. This has been found effectual in the case of the Sheffield water, which contains a free acid. It is the safest method of dealing with such waters as are known to take up lead readily, but it must be borne in mind that there is this difference between erosion and plumbo-solvency, that any mere neutralising treatment, even if carried out imperfectly, always renders an acid water, as regards plumbo-solvency, less dangerous than before; whereas, as regards erosive ability, insufficient treatment may produce no appreciable inhibition, and may in certain cases render such partially treated water more prone than before to attack lead. The alternative plan is to use pipes that do not yield lead to water, such as cast- or wrought-iron pipes, and if possible they may be glazed internally. Leaden pipes lined with tin are very liable to fracture of the lining metal when the pipe is bent, and the water being exposed to both metals, galvanic action is set up, when the lead, as being the more oxidisable metal, is dissolved. Block-tin pipes are very expensive and have the further disadvantage of being eaten through, apparently in consequence of the presence of nitrates in the water. On the whole, good iron pipes appear to be the safest.

In cases where doubt exists as to the plumbo-solvent ability of a water, it is advisable that before it be deemed safe, such a water should give a neutral reaction with lacmoid solution of an ascertained activity, and also fail to dissolve an appreciable quantity of lead when filtered through a glass tube containing lead shot. Similarly, all doubtful waters should be tested as regards erosive ability by placing them in contact with bright lead. A water containing as much as $\frac{1}{10}$th of a grain of lead in the gallon is unfit for drinking purposes, and even $\frac{1}{20}$th of a grain may be unsafe, as this amount has been known to affect some persons. Filtration through sand, charcoal or spongy iron will remove lead from water.

IMPURITIES OF WATER.

The origin of the impurities of water may be referred to four heads, viz., substances derived from the source, impurities added during transit from source to reservoir, impurities acquired during storage, and impurities the result of faulty distribution. The chief actual impurities may be classed into two kinds, viz., the mineral and the organic; these latter may have either an animal or vegetable origin. The mineral impurities are in solution, while the organic are, for the most part, in suspension, as represented by disease-producing bacteria and ova of parasitic worms; some organic impurities, however, are in solution in water existing as nitrogenous compounds or salts, the final products of the breaking down of vegetable and animal material derived from sewage gaining accidental access to the water. From the sanitary point of view, more importance attaches to the suspended organic impurities than to those in solution, whether mineral or organic.

Impurities derived from the Source.—The geological formation of a district necessarily influences the composition of the water running through it, though it is impossible to tell with absolute certainty what the constituents of the water may be. Formations vary greatly, and the broad features laid down by geologists do not always suffice for our purpose. In the middle of a sandy district, yielding usually a soft water, a hard selenitic water may be found; and, instead of the pure calcium-

carbonate water, a chalk well may yield a water hard from calcium sulphate and iron. Still it may be useful to give a short summary of the best-known facts.

Water from springs in Granite and Gneiss is very pure and of most excellent quality for drinking, cooking, and all domestic purposes; hardness is usually very trifling; the organic matter is in very small amount. The water is bright, clear, and palatable, and has nearly a uniform temperature throughout the year.

The Silurian rocks, consisting of shales, slate, sandstones, &c., contain more soluble matter than is met with in Granite or Gneiss, and consequently yield to water a larger amount of solid material, nearly the whole of which consists of innocuous salts. The proportion of organic matter is small, and the water is generally soft. The water is clear and sparkling, and is well adapted for drinking, cooking, and washing purposes.

Water from springs in the Devonian rocks and Old Red Sandstone is generally of most excellent quality. The organic matter is in very small amount. The water is usually soft or of moderate hardness.

Of the Carboniferous rocks, the mountain limestone yields water clear, colourless, and palatable; it is rather hard, and therefore not well suited for washing purposes, but it may be effectually softened by Clark's process. The total solid constituents average about 26 parts per 100,000. The waters from the millstone grit are very similar. The hardness varies considerably; they contain only a trace of organic matter.

Unpolluted waters from the Lias clay are clear, colourless, palatable, and wholesome. They contain only a trace of organic matter, but are rather hard. Some of these waters are found to contain a large proportion of solid matters in solution, nearly the whole of which consist of mineral matters. Water from Hard Oolite is very pure—and although the waters are hard, the hardness is chiefly of a temporary kind. As water-bearing strata, or as a subterranean reservoir for the purification and storage of water, the Oolite rocks are equal, if not superior, to the chalk.

Water from the Cretaceous rocks, such as the Hastings Sand and the Lower Greensands, is pure and wholesome. The hardness varies within wide limits, but although usually a very hard water, it admits of softening. Water from the Chalk is very sparkling and clear, and is highly charged with carbonic acid. The total solid matter averages about 30 parts per 100,000, and consists of mineral salts, which are not unwholesome; organic matter is usually in small amount. The water is sparkling, colourless, palatable, and wholesome. Any excess of hardness is of the temporary kind, and can be easily removed.

Springs in the Drift and Gravel yield water of very variable quality, owing to the varying character and generally small thickness of the beds through which it percolates. It usually holds in solution a large proportion of organic constituents, although it sometimes contains only a small amount of organic matter. Water from Magnesium Limestone differs from the Chalk waters in containing a large amount of permanent hardness. The salts present are chiefly sulphate and carbonate of calcium and magnesium. The water is organically very pure, but it is too permanently hard to be a wholesome drinking water.

Water from shallow wells in Alluvium and Gravel soils are generally impure, with calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally, the organic matter oxidises rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been

contaminated with sewage. The amount of solids per 100,000 varies from 30 to 170 parts or even more.

Wells sunk in Gravel on the London Clay yield a bright and palatable water, but are generally polluted, their chief sources of supply being from sewers and cesspools. The water is unfit for drinking and washing purposes. All surface and subsoil waters are very variable in composition, often very impure and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or on hard millstone grit, may supply a pure water, which may, however, be sometimes slightly coloured with vegetable matter. Cultivated lands, with rich manured soils, give a water containing both organic matter and salts in large quantity. Some soils contain potassium, sodium, and magnesium nitrates, and yield these salts in large quantity to water. In towns and among the habitations of men, the surface-water and the shallow-well water often contain large quantities of calcium and sodium, nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrate being first formed, which dissolves large quantities of lime. Organic matter generally exists in large amount, and slowly oxidises, forming ammonia and nitric acid; the bacterial content of these waters is usually considerable and of dangerous quality.

Marsh-water always contains a large amount of vegetable organic matter. Suspended organic matter is also common. The salts are variable. A little calcium and sodium in combination with carbonic and sulphuric acids and chlorine are the most usual. Of course, if the marsh is a salt one, the mineral constituents of sea-water are present in varying proportions.

Water taken from wells sunk in the vicinity of cemeteries contains ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter. The water from old graveyards (disused) may show less organic matter, as evidenced by bacteria, but it will contain large quantities of nitrates, chlorides, &c.

The water derived from deep Artesian wells is usually of excellent quality, and contains only a very minute quantity of organic matter. In some cases, however, the water is so highly charged with saline material as to be undrinkable. When not very hard, these waters are of good quality, clear and colourless, and, owing to the depth of the well, are usually of a uniform temperature throughout the year. The water is not well aërated, and therefore not so palatable as spring-water. Some Artesian-well waters are warm; these are generally used for medicinal purposes. Others, again, contain iron or are aperient; these are unfitted for ordinary drinking purposes. The Artesian wells in London are alkaline from the presence of bicarbonate of sodium, and hence are very soft. Water from wells near the sea frequently contains so much saline matter as to taste quite brackish, although the organic matter may not be very large.

Rain-water may be contaminated by washing the air it falls through, but more by matters on the surface on which it falls, such as decaying leaves, bird droppings, soot, or other matters on the roofs of houses; it also takes lead from lead coatings and pipes, and zinc from zinc roofs. If stored in underground tanks it may also receive soakings from the soil through leakage.

Impurities added during Transit from Source to Reservoir.—Open conduits are liable to be contaminated by surface washings carrying in finely divided clay, sand, chalk, and animal matters from cultivated land; and the leaves and branches of trees add their contingent of vegetable matters. These impurities may occur in most cases, but in

addition the refuse of houses, trades, and factories is often poured into rivers, and all sorts of matters are thus added.

The very numerous animal and vegetable substances derived from habitations are usually classed under the vague but convenient term "organic matter," as the separation of the individual substances is impossible. Practically the whole of this organic matter is nitrogenous and, undergoing disintegration, forms ammonia and oxidised salts of nitrogen. Associated with this organic matter and constituting its most dangerous elements are innumerable bacteria, which, if derived from sewage, especially the effete material from specific diseases, such as enteric fever, dysentery and cholera, are a certain and fertile source of water-borne disease.

During its flow in open conduits, purification goes on, by means of subsidence, by the action of the ordinary water bacteria on pathogenic micro-organisms, should these be present in the water, by exposure to direct sunlight, and by the presence of water plants. It must be remembered that the natural habitat of pathogenic bacteria is the interior of the human body; when they pass from this into rivers, they are in an unnatural medium, in which they can only maintain their existence and power of multiplication for a limited period and tend rapidly to disappear under the conditions found in ordinary river-water.

Impurities of Storage.—The chance of substances getting into the water of wells and tanks, and even of cisterns in houses, is very great. Surface washings and soakage contaminate wells and tanks, and leakages from pipes, passage of foul air through pipes, or direct absorption of air by an uncovered surface of water, introduce impurities into cisterns. It is singular in how many ways cistern and tank waters get foul, and what care is necessary, not only to place the cistern under safe conditions at first, but to examine it from time to time to detect contamination of the water. In India especially, the "tank" water is often contaminated by clothes washed near, or actually in, the tank; by the passage, even, of excrement directly into it, as well as by surface washings, so that in fact in some cases the village tank is one of the chief causes of the sickness of the people. There is, perhaps, no point on which the attention of the sanitary officer should be more constantly fixed than that of the storage of water, either on the large or small scale.

Impurities of Distribution.—If water is distributed by hand, *i.e.*, by water-carts, barrels, or skins, there is necessarily a great chance of its being fouled. In India, where the water is generally carried by water-carriers (Bhisties), inspection of the carts or skins should be systematically made, and whenever it be possible, pipes should be substituted for the rude method of hand conveyance. But even pipes may contaminate water; metals (lead, zinc, and iron) may be partly dissolved; wood rots, and if the pipes are occasionally empty, impure air may be drawn into them, and be afterwards absorbed by the water. Buchanan, in his Report on an Outbreak of Fever at Caius College, Cambridge, showed that this was due to foul trap-water sucked in from the closets. In towns supplied on the intermittent system, when the pipes are becoming empty the flow of water from a tap has drawn dirty water or air through a pipe at some distance, and in this way even the water of the mains has been fouled. Even with the constant system similar evils are not impossible, as a water-main running full can suck up impurities, such as coal-gas or sewage, from the surrounding soil, if a defect in the pipe exists. Cases of this kind render it important that water-mains be not only well jointed, but so laid that they are not in

close proximity to gas-pipes, drains, or sewers; probably the safest plan is to have all pipes in subways, where they can be inspected and defects readily remedied.

EFFECTS OF AN INSUFFICIENT OR IMPURE SUPPLY OF WATER.

Insufficient Supply.—The consequences either of a short supply of water for domestic purposes, or of difficulty in removing water which has been used, are very similar. The want of water leads to impurities of all kinds: the person and clothes are not washed, or are washed repeatedly in the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself. The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and ophthalmia in some cases, are thus propagated. It also appears likely that the remarkable cessation of spotted typhus among the civilised and cleanly nations is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

Little is known with certainty of the effects produced on men by deficiency in the supply of water. Under ordinary circumstances, the sensation of thirst, the most delicate and imperative of all our feelings, never permits any great deficiency for a long time, and the water-removing organs eliminate with wonderful rapidity any excess that may be taken, so as to keep the amount in the body within certain limits. But when circumstances prevent the supply of water, it is well known that the wish to drink becomes so great that men will run any danger, or undergo any pain, in order to satisfy it. The exact bodily condition thus produced is not precisely known, but from experiments on animals and men, it would appear that a lessened amount of water in the body diminishes the elimination of the pulmonary carbonic acid, the intestinal excreta, and all the important urinary constituents.

The more obvious effects produced on men who are deprived for some time of water is, besides the feeling of the most painful thirst, a great lowering of muscular strength and mental vigour. After a time exertion becomes almost impossible, and it is wonderful to see what an extraordinary change is produced in an amazingly short time if water can be then procured. The supply of water becomes, then, a matter of the most urgent necessity when men are undergoing great muscular efforts, and it is very important that the supply should be by small quantities of water being frequently taken, and not by a large amount at any one time. The restriction of water by trainers is based on a misapprehension: a little water, and often, should be the rule.

Effects of Impure Water.—From the earliest times, the evil effects of drinking impure water has been recognised, but it is only within quite recent years that the real relation between disease and water-supply has been truly appreciated. In the past, the phenomenon was attributed to the most obvious forms of contaminating material, but modern research shows that water-borne diseases are due to the pollution of the water by specific germs or bacteria, and in proportion as the medium is richer or poorer in this kind of suspended matter, so is its consumption attended with

danger or safety. Two diseases stand out pre-eminently as being related intimately with the consumption of specifically contaminated water, these are cholera and enteric fever, while some other maladies may with more or less certainty be attributed to a similar cause. The facts in respect of each are worth considering in some detail.

Cholera.—There is ample evidence to show that water plays a most important part in the diffusion of this disease, and to Snow's investigations during 1849 must be attributed the merit of first discovering this fact.* In 1854 occurred the celebrated incident of the Broad Street pump in London, which was investigated by a committee, whose report contains the most convincing evidence that, in that instance, the poison of cholera found its way into the body through drinking water.

In 1865 occurred the important outbreak at Newcastle-on-Tyne, when all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 also was the remarkable and undoubted case of water-poisoning at Theydon Bois, and in the following year the violent outbreak in the east of London was shown to be connected with the circulation of impure water by the East London Waterworks Company. The district supplied with water from this source was the sole area of intense cholera in London; the disease limiting itself "almost exactly to the area of this particular water-supply, nearly, if not absolutely, filling it, and scarcely at all reaching beyond it." †

In further confirmation of the view that water is a fertile agent in spreading the disease, the following instances may be adduced.

The epidemic of cholera in Hamburg in 1892 was a remarkable instance in which this disease may be spread through the agency of water. "Hamburg, Altona, and Wandsbeck are three towns which adjoin each other and really form a single community; they do not differ except in so far as each has a separate and different kind of water-supply. Wandsbeck obtains filtered water from a lake, Hamburg until recently obtained its water in an unfiltered condition from the Elbe just above the town, and Altona obtains filtered water from the Elbe below the town Whereas Hamburg was visited with a severe epidemic of cholera, Wandsbeck and Altona, if one excepts the cases brought thither from Hamburg, were nearly quite free from the disease. On both sides of the boundary the conditions of soil, buildings, sewerage, population, everything of importance, were the same, and yet the cholera in Hamburg went right up to the boundary of Altona and there stopped." In this large population on each side of the boundary nearly all the factors were the same except the water-supply. The population supplied with the unfiltered water from the Elbe suffered severely from cholera, while the population supplied with carefully filtered water from the same source escaped.

In the cholera epidemic in Warsaw in 1892 the majority of cases occurred in people living on the banks of the river, every one of whom had drunk unboiled water taken directly from the river. When the practice of taking water from the river was put a stop to and boiled water was generally provided, cases of cholera ceased. In fact the whole history of cholera during 1892 in Europe showed that it was by means of water in almost every instance that the disease was spread.

Our experiences in India teach the same lesson. In 1867 the appearance

* Snow: *Registrar-General's Report on Cholera in England*, 1848–49; also *On the Mode of Communication of Cholera*, London, 1855.

† Radcliffe: *On Cholera in East London*, Report of Medical Officer to the Privy Council, 1865.

of cholera and its rapid spread among the vast crowd of pilgrims after the great bathing day at Hurdwar on the Ganges was a case of water infection on a gigantic scale. In 1879 a similar outbreak occurred, and again in 1892, from whence cholera spread to Russia. If we look at the remarkable results which have followed on the supply of pure water to European troops in India, the evidence is even stronger. From 1850 to 1885, the average mortality among them from this disease was 17 per 1000. From 1886 to the present time it has been less than 1 per 1000. The only notable difference in the conditions between the two periods is the improvement in the quality of the water supplied and issued to troops during later years. Among native troops, in whom the need of water discipline is more difficult of development, our experiences are not so satisfactory, as explosive outbreaks of cholera are not infrequent even now, a recent and notable case in point being the incidence of the disease among the men of the 19th Punjab Infantry at Kohat in 1899. Both that city and the adjacent cantonment are supplied with an excellent piped water-supply derived from a well-protected spring in the neighbouring hills, but the locality is provided also with an extensive system of irrigation, the canals for which run as open conduits through both the city and cantonments. Cholera was imported into Kohat City from the Punjab on July 3, and rapid infection of the open irrigation canals followed with consequent cases of the disease among those who thoughtlessly used the irrigation water instead of that supplied from the stand-pipes. On July 6, the 19th Punjab Infantry arrived absolutely free from cholera and encamped on ground near which irrigation water ran. In spite of the fact that safe water from stand-pipes was available on the camping-ground, and in the absence of specific warning from the local staff officer that the irrigation water was unsafe, the men of the regiment consumed large quantities of the water from the irrigation channels. Within forty-eight hours, there had occurred 87 cases of cholera in the regiment, with 29 deaths. The removal of the corps at once to a camp away from irrigation water, and supplied solely from the piped supply, rapidly stopped the outbreak; but not until there had been 126 attacks with 56 deaths in this regiment alone. The total cases occurring in the garrison between July 3 and 19 was 314, with 151 deaths, and each case was directly traceable to use of irrigation water, while among those who studiously avoided this water not a single attack occurred.

There are some who even still deny that cholera is a water-borne disease, but in the face of the weight of evidence to the contrary, their number is rapidly diminishing. The only serious argument advanced in support of their view is, assuming that the comma bacillus described by Koch is the actual cause of cholera, this bacillus would soon be destroyed by the putrefactive organisms present in such water. This objection loses its force when it is remembered that, under circumstances under which cholera alone prevails as an epidemic, the infectious matter has every chance of being imbibed by others almost immediately after it reaches the water.

Enteric Fever.—It is now generally accepted that the poison of enteric fever exists in the excretal discharges, especially the urine, of those suffering from the disease, and if these gain access to water, it becomes one of the chief agents in the distribution of the disease. The micro-organism associated with enteric fever is a rod-shaped bacillus described by Eberth and Gaffky. That water may be the means of propagating this disease has long been admitted by those who have made the subject their special study, and is borne out by the researches of Jenner, Budd, Simon, and Hirsch, who consider that few points in the etiology of enteric are so

certainly proved as the conveyance of the poison by drinking water or by food contaminated with infected water. Many instances are recorded showing the connection between this disease and an impure water-supply long before the specific organism which is associated with it was recognised.

An interesting outbreak is that of Lausen in Switzerland, which occurred in 1872. The cases were confined to those who drank water from a certain spring. On the other side of a hill, 300 feet high, was a brook contaminated with enteric excreta : when this Fürler brook was dammed up to water the meadows, it was noticed that the spring at Lausen became turbid and bad tasting. Shortly afterwards 10 persons were attacked in one day, and 57 more in the nine days following. Salt was put into the Fürler brook, and its presence detected in the water at Lausen, clearly showing a direct connection.

A destructive outbreak took place at Caterham and Redhill during 1878. This was traced to contamination of the water-supply by the stools of a workman suffering from mild enteric fever, who was employed in the company's wells. The disease was confined to those who consumed the water, and ceased after the wells were pumped out and cleansed. The inmates of the Lunatic Asylum and the detachment of troops at Caterham barracks used the water from the asylum well, and did not suffer.

An epidemic occurred at New Herrington, Durham, in April 1889 : 275 cases were reported between April 1 and June 7, when the epidemic may be said to have ceased. The cause was traced to the pollution of a deep well (330 feet) by the overflow from a tank containing farm sewage, situated three-quarters of a mile above this well. The overflow escaped and disappeared down a fissure in the ground, which entered the well through a crack in the steining 45 feet below the surface. Two tons of salt were thrown down this fissure, and the chlorine, entering the well through the "feeder," rose from 4 to a maximum of 24 grains per gallon. Specific contamination, however, of the farm-house sewage could not be made out, no illness resembling enteric fever having been known there for some years.

One of the most remarkable and extensive epidemics of enteric fever was that which prevailed in 1890-91 in the Lower Tees Valley. Enteric fever attacks occasioning the first outburst were most marked during a six-weeks' period, September 7 to October 18, 1890; that occasioning the second outburst during a six-weeks' period, December 28, 1890, to February 7, 1891. The total number of enteric cases in the ten Registration Districts, forming the area under consideration, in the two six-weeks' periods referred to, were 1463. Of these 1334, or 91 per cent., occurred in three out of the ten districts, namely, those of Darlington, Stockton, and Middlesbrough, all of which were supplied with water taken from the River Tees. The estimated population in the ten Registration Districts receiving their supply of water from the River Tees amounted to 219,435, whereas the estimated population receiving their water from other sources than the Tees reached 284,181. Calculating the attack rates upon these figures, it was found that the rate of attack from enteric fever per 10,000 living during the first six-weeks' epidemic had been 33 amongst persons supplied with the Tees water and 3 amongst persons supplied with other water ; whereas in the second six-weeks' epidemic the rates were 28 and 1 respectively. Above the intakes of the water company, the Tees receives either directly or indirectly the drainage of twenty villages and hamlets as well as that of the town of Barnard Castle.

Worthing was visited with a severe outbreak of enteric fever in 1893. Between May 3 and November 30, 1315 attacks are known to have occurred

in the borough, with 168 deaths. After the first three weeks the epidemic abated considerably, only to recur in the month of July with an outbreak of remarkable intensity. On investigating into the circumstances which led to the epidemic of this disease, it was shown that it was intimately related in point of time to the admission to the Worthing service mains of water from a new source of supply, undertaken in order to obtain an increase of water for the borough; that thereafter the disease became general throughout the areas supplied by this service, and that within the limits of these areas the incidence of fever was almost wholly on houses supplied with this water. It was further shown that not only was this new source of supply open to dangerous contamination, but that also, on bacteriological examination, subcultures presented, morphologically as well as culturally, all the characters of the enteric fever bacillus. In this case the water was contaminated by sewage which flowed through a fissure communicating with the new well; the sewers being jointed with clay and permitting leakage into the soil. It was also noted that there was comparative immunity from enteric fever of persons who habitually consumed water from local wells; and that there was heavy incidence of the disease on those who used the water delivered by the public service supply. Moreover, the water was not filtered.

It would not be difficult to quote many other instances of a similar nature where wholesale infection of a community has followed accidental fouling of the public water-supply with sewage containing enteric material: the more notorious of recent occurrences of the kind are the outbreaks at Maidstone in 1897 and at Lincoln in 1905. In the former case an outbreak affecting upwards of 1800 persons occurred as the result of contamination of the Farleigh springs which were the source from which the Maidstone water company drew its supply. At Lincoln, the only sources of water available were the river Witham and its tributaries, all of which were constantly being contaminated with sewage and other manurial matter. The water drawn from these doubtful sources was submitted to sand filtration before distribution, but, owing to frost and the undue hastening of the rate of filtration during December 1904, this safeguard broke down, with the result that an outbreak of enteric fever began on January 22, 1905, and continued until June 21, the total number of cases being 1021, or two per cent. of the total population, with a death-roll of 120. The whole of the evidence regarding the outbreak shows its direct cause to have been undoubtedly the wholesale distribution of an imperfectly filtered water drawn primarily from sources open to persistent sewage pollution. In practically every epidemic outbreak of enteric fever the story is the same, and it is unnecessary to quote further illustrations of the dominant part which water plays in the dissemination of this disease.

There has been some difference of opinion as to whether sewage *per se* will produce enteric fever, or must the evacuations from an enteric fever patient pass into the water. This is part of the larger question of the origin and propagation of specific poisons. Those who believe in the evolution of species have perhaps good grounds for considering that any sewage, receiving fæcal matters, may give rise to this specific form of fever; but as yet the weight of evidence is against such taking place.

Diarrhœa and Dysentery.—There is ample evidence to show that both these affections may and often do result from drinking impure water, but when thus produced are probably due to a variety of impurities in the water. Thus an excess of suspended matter, such as clay, marl, or fine sand, so common in many rivers in Asia and Africa, will produce diarrhœa

in persons unaccustomed to the water: these fine particles of mineral matter excite mechanically the alimentary mucous membrane and act as direct irritants. Even vegetable matter consisting of the *débris* of plants in a state of minute subdivision and suspended in water has been known to give rise to similar symptoms. In the present state of our knowledge regarding the exact cause of many forms of diarrhœa it is difficult to say what part bacteria play in their causation, but arguing from the analogy of other diseases of like nature it is only too probable that the presence of more or less specific micro-organisms in dirty waters is the real explanation of their ability to give rise to diarrhœa; this is undoubtedly the case in sewage-polluted waters.

Dissolved mineral matters, when in excess, may produce diarrhœa. Sulphates of lime, soda, and magnesium are the most usual as producing this effect, as is seen in the case of many purgative medicinal waters. Hydrogen sulphide, as well as the nitrates of calcium and potassium, will give rise to diarrhœa also.

The instances in which outbreaks of dysentery have been traced to the use of impure water are very numerous, and the substitution of a clean for a dirty or foul supply has been usually followed by a decrease in the prevalence of the disease in an affected community: the experience of armies is sufficiently well known to emphasise this fact. In a large number of instances, the water which gave rise to dysentery was polluted with fæcal and possibly dysenteric discharges; as we have considerable reason to believe that dysentery is caused by a specific micro-organism, in some cases a bacillus and in others an amœba, it is easy to understand that water may serve, not only as a vehicle by means of which the specific cause may be introduced into the system, but it may serve also as an irritant and thus act as a predisposing cause of infection.

Dyspepsia.—Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and magnesium salts. Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened the prevalence of dyspeptic complaints. It is a well-known fact that grooms object to give hard water to their horses, on the ground that it makes the coat staring and rough—a result which has been attributed to some derangement of digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 11 parts per 100,000 of each substance individually or collectively appears to be injurious to many persons. A much less degree than this will affect some persons.

Goitre.—The opinion that impure drinking water is the cause of goitre is as old as Hippocrates and Aristotle, and has been held by the majority of physicians. The opinion may be said actually to have been put to the test of experiment, since both in France and Italy the drinking of certain waters has been resorted to, and apparently with success, for the purpose of producing goitre, and thereby gaining exemption from military conscription.

Apart from this, the evidence for the causation by water is extremely strong, many cases being recorded where in the same village, and under the same conditions of locality and social life, those who drank a particular water suffered, while those who did not do so escaped.

The impurity in the water which causes goitre is not yet precisely known. It is certainly not owing to the want of iodine, as stated by Chatin, and there is little probability of its being caused by a deficiency of chlorides, by fluorine, or by silica. On the other hand, the coincidence of goitre with sedimentous water is very frequent. Since the elaborate geological inquiries of Grange and the analysis of the waters of the Isère, magnesium salts in some form have often been considered to be the cause, to which many add lime salts also ; and certainly the evidence that the water of goitrous places is derived from limestone and dolomitic rocks, or from serpentine in the granitic and metamorphic regions, is very strong. There are, however, not wanting analyses of water of goitrous regions which show that magnesia may be absent, while it has been denied also that there need be any excess of lime. One fact is noteworthy, it is that nearly all goitrous localities are situated in hills or mountain valleys, and that it is during and after the rains, when the streams, so far as their mineral ingredients are concerned, must be in the state of greatest dilution, and so far as their suspended matters are in a state of greatest impurity, that the disease most commonly commences and develops most rapidly.

McCarrison's * recent observations on endemic goitre in the Chitral and Gilgit valleys indicate that the water-supply of Gilgit was the vehicle of the spread of the disease. At its source it was able to produce 11·8 per cent. of goitre; at its terminus, after passing through seven villages, it caused 45·6 per cent. There must, therefore, between source and terminus, have been added some poisonous element, which might be either inorganic substances or micro-organisms. The incidence of the disease in the adjacent territory of Nagar could only be explained on the latter assumption, leading to the spread of goitre in a typically epidemic form. In the absence of more specific evidence, it is difficult to accept altogether the bacillary theory, but whether the result of micro-organisms or mineral material in water, there is little doubt that goitre is intimately associated with the habitual consumption of certain kinds of water, the probable causal agent being in suspension, as filtering seems to lessen the danger. Rain-water has never been known to produce goitre, and it is said that a recent goitre would subside if rain-water were drunk. That there is a connection between water and goitre causation is undoubted, but what the responsible factor is needs further extended inquiry ; the weight of evidence suggests that water is merely the vehicle by which the causative agent, possibly a protozoon, reaches man from the soil.

Malaria and Yellow Fever.—A considerable literature exists suggesting the diffusion of these two diseases by means of drinking water. Many of the observations adduced in support of this view do not bear the constructions that the writers put upon them. In the light of modern knowledge regarding the natural history of both malaria and yellow fever, we are disposed to think that any possible connection between water and these affections is explicable by the fact that water is essential for the development of their associated insect hosts : in other words, no water no mosquitoes, and no mosquitoes means neither malaria nor yellow fever.

Other Zymotic Diseases.—It has been suggested that diphtheria and scarlet fever may be disseminated by the agency of drinking water, but the evidence at present is against such being the case. In no single instance has water been identified as the probable cause of diphtheria in the investigations undertaken by the Local Government Board. As a matter of fact, the diphtheria organism exists with difficulty in water.

* McCarrison, *Brit. Med. Journal*, April 14, 1906 ; also *Lancet*, 1906, vol. ii. p. 1570.

It can apparently only maintain existence in very polluted water, but average water is to a large extent destructive to its vitality. As regards scarlet fever, although there seems no *primâ facie* reason against water being a channel of infection, evidence that it is so is wanting; this disease certainly is not disseminated by water as a rule.

Parasitic Diseases.—It has long been recognised that water constitutes a common medium by which certain parasites may reach man, but the number of instances in which it is a direct means of infection appears to be small. In the majority of cases water is merely the normal habitat of the intermediate hosts.

The eggs of *Distomum hepaticum* are developed in water, and the embryos swim about and live, so that introduction in this way for sheep is probable, and for men is possible.

The *Ascaris lumbricoides* appears also sometimes to enter the body by the drinking water. At Moulmein, in Burmah, during the wet season, and especially at its commencement, natives and Europeans, both sexes and all ages, were, in former years, so affected by lumbrici as almost to constitute an epidemic. The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Similar facts have also been noticed in England. Leuckart has no doubt of the passage of the *Ascarides'* eggs into drinking water; and, indeed, they have been actually seen in the water by Mosler. But it seems yet doubtful, as all experiments have failed in producing from the drinking water the worms in animals, whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine.

The *Ankylostoma duodenale* would appear from Leuckart's statement to be introduced by drinking water, though possibly in the light of Looss's recent work an equally frequent channel of invasion is by the skin. In any case surface-water constitutes a suitable medium for the ova and larval stage of this parasite. The *Oxyuris vermicularis*, or thread-worm, is probably distributed occasionally by the same medium.

Filaria Dracunculus.—The introduction by water of Guinea-worm has long been a favourite opinion. It has been a matter of debate whether it is taken into the stomach as drink, and thence finds its way into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The former opinion seems to be the more probable in the majority of cases. Fedschenko has shown that the embryo enters the body of a *cyclops*, which acts as its host, and that it undergoes development there, and is thus taken in with drinking water. Boiling the water before drinking appears to have a prophylactic effect.

Filaria sanguinis hominis appears to find its way into the blood of man through water in a curious way. Manson has found that the mosquito is an active agent in the propagation of *Filaria*. The embryos are taken into the mosquito's stomach with the blood of persons infected by the hæmatozoon. Arrived there, the parasite penetrates the walls of the stomach, and works its way to the thoracic tissues of the insect, where further development takes place. Thence they are transferred to the water, whence it is assumed that it again finds entrance into the body of man. It produces *Elephantiasis* and *chyluria*.

Bilharzia hœmatobia.—From the observations of Griesinger, John Harley, and Cobbold, there seems no doubt that the embryos of this entozoon live in water, and the parasite may be thus introduced either

directly, or by the medium of some animal. Sonsino states that the intermediate host is a small fresh-water crustacean.

Small leeches may be present in water, which fix on the pharynx, or in the posterior nares, after drinking. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously.

Lead, Arsenic, Copper, Zinc, &c., in Water.—The question of lead poisoning by drinking water has already been considered. It is only necessary to mention the fact that metals pass into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces. The amount of copper required to produce poisonous symptoms appears to be doubtful. Iron is a not infrequent impurity in water. In quantities sufficient to give a slight chalybeate taste it produces often dyspepsia, constipation, headache, and general malaise. Custom sometimes partly removes these effects.

PURIFICATION OF WATER.

The purification of water may be necessary to remove excessive hardness, gross suspended matter, or the micro-organisms usually associated with specific diseases. A variety of procedures have been suggested and used for these purposes, and their applicability depends much upon whether it is intended to purify the water in bulk or large volumes, or whether the act of purification is to be applied to small quantities only. Among the methods suitable for dealing with water under one or other of these conditions may be mentioned those aiming primarily at removal of excessive hardness, various filtration processes, the employment of heat, and the addition of chemicals.

Softening of Water.—Certain waters, notably those from the chalk and magnesian formations, are rich in salts of the alkaline earths, such as calcium, magnesium, barium, &c. The presence of these salts renders a water "hard," and for economic reasons mainly it is necessary to remove these so-called hard salts, or, in other words, soften the water. Several methods have been used, but the basis of all of them is the addition of a measured quantity of milk of lime, calculated on the degrees of hardness of the water. Carbonates of lime and magnesia constitute the main part of the hard salts of an ordinary water, and these are soluble in water containing free carbon dioxide. When a solution of fresh lime is added to such a water in proportion to the degree of hardness present, the lime combines with the excess of carbon dioxide to form carbonate of lime, which is precipitated with almost the whole of the carbonate of lime originally held in solution by the water, and falls as a sediment, carrying down with it the organic impurities held in suspension; this action of adding lime-water to remove the mineral matters (the salts of lime and magnesia) from a water may be expressed as follows:—

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O.$$

It is necessary to know the exact degrees of hardness in the water, and to use only so much milk of lime as will combine with the carbon dioxide holding the chalk in solution, otherwise lime passes out into the distributing pipes. If an excess has been added, a few drops of a solution of nitrate of silver added to a small quantity of the water will produce a dark yellow colour, but only a white precipitate if chlorides alone are present. The amount of lime added averages about one ounce per 100 gallons for each degree of temporary hardness. This treatment usually leaves only the

permanent hardness *plus* some 2 grains per gallon of calcium carbonate in solution. In the Porter-Clark process, the suspended matters are removed by allowing the water to pass through a series of linen cloths under pressure. This has the advantage of rapidity, and removes the whole of the suspended matters effectually.

The permanent hardness of water is not touched by this process; this hardness is due to the soluble salts of lime or magnesia held in solution by the solvent properties of the water itself.

For the reduction of permanent hardness, the addition of lime, sodium, or sodium carbonate are needed, thus:—

$$CaSO_4 + CaCO_3CO_2 + 2NaOH = 2CaCO_3 + Na_2SO_4 + H_2O.$$

In waters where great permanent hardness is due to lime salts, then sodium carbonate must be used instead of caustic soda, thus:—

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$

In both cases, the addition of lime is needed for removal of the temporary hardness. Practically each degree of hardness, as calcium carbonate, is equal to 0·8 part of caustic soda, 0·56 part of lime, 0·74 part of $Ca(OH)_2$, 1·06 part of Na_2CO_3, and for general use the following rules may be laid down:—

(1) If the temporary hardness exceeds the permanent hardness, add NaOH equivalent to the permanent hardness, and lime equivalent to the excess of temporary over permanent hardness.

(2) If the permanent hardness due to lime exceeds the temporary hardness, add Na_2CO_3 in proportion to the permanent hardness, and then, if necessary, lime equal to the temporary hardness.

Filtration.—Water is nearly always submitted to some process of filtration before distribution; it is extremely difficult to obtain at its source a water which needs no purification, and in the great majority of cases it is impossible to do so. It is the practice of most water companies to use sand and gravel as a filtering medium. The water to be treated is passed first into settling reservoirs, where sedimentation is allowed to take place for some thirty hours. From these settling basins the water is led to the influent chambers of the filter-beds. Each influent chamber has two compartments; in the first is placed a balanced valve connected by means of a lever to a float in the second compartment, by means of which, when the water on the filter reaches the desired elevation, the valve is closed automatically. The water flows upon the filter-bed through two openings in the side of the influent chamber. The filter-beds are rectangular in shape, with impermeable walls, and are usually filled from above downwards with about 40 inches of sand, effective size 0·3 to 0·34 mm., and 24 inches of gravel in different sizes, so arranged that the upper finer material cannot penetrate the lower coarser material, and the latter cannot enter the collecting drains. The water, after it has percolated through the sand and gravel, is received in the collecting drains. The usual head of water allowed on a filter-bed is 36 inches, and the rate of flow or filtration varies from 2·5 to 4 inches per hour, giving a delivery of from two to two and a half million gallons of water per acre of filter-bed. When one of these filters has been working some time it requires a head in excess of the maximum allowed, which rarely exceeds 42 inches, in order to give the normal filtered delivery. Under these conditions the filter is taken out of service, emptied, and the top layer of sand renewed, not more than half an inch being scraped off at each cleaning. When, by repeated cleaning, the layer of sand has been reduced to 16 inches in thickness, the filter is thrown out of action and the bed remade with washed sand. After cleaning, the filter-bed is refilled

with filtered water from below upwards until it stands at a depth of about 8 inches above the sand ; the impure water is then run on up to the required head, and after the bed has been standing for twenty-four hours, filtration is again started.

Experience shows that efficient filtration of water through sand and gravel beds cannot be obtained if the rate of flow exceeds 4 inches in the hour ; as a rule, 98 per cent. of the bacteria are removed from a water when so filtered. The efficient working of these filters depends upon the formation of a slimy layer on the surface, and, to some extent, in the body of the filter-bed. This slimy layer, to which the greatest importance is now attached, consists of zooglœa of bacteria combined with suspended materials in the water ; it is extremely friable and readily broken by excessive pressure on the surface or disturbance of the body of the filter-beds. Hence the extreme care now taken to fill the filter-beds from below so as to prevent the zooglœa masses being broken by the pressure of air, and to control the rate of filtration and limit the pressure of water on the surface. The degree of fineness and uniformity of the sand grains are also of importance in securing a good filtrate. By using fine sand the current of water which passes through a bed is rendered slow and uniform, and the walls of the lacunar spaces are approximated, permitting molecular action to take place and giving greater firmness to the gelatinous layer. Hence the work of a filter-bed is partly mechanical and partly vital.

Owing to their relatively slow rate of filtration, and the expense, care, and time needed for their cleansing and resting, the gravity sand and gravel filter-beds have been subjected to some criticism. As an outcome of this criticism, what are known as " mechanical filters " have been devised. The essential idea in these installations is to dose or prepare the water with from $\frac{1}{10}$th to 1 grain of sulphate of alumina per gallon, which instantly produces a gelatinous, sticky coating of insoluable hydrate of alumina on the sand bed ; this serves as an adjuvant to the filter for the holding back and arrest of fine suspended matter and micro-organisms in the water passing through. Filters of this kind have been in use in America for some years, and an efficient representative of the type in this country is the Bell Patent Filter. The aluminated sand is contained in steel drums and the water passed through under pressure. These filters can purify a million gallons of water per day on an area of 600 square feet, the percentage of contained bacteria removed from the water being said to be equal to that obtained by the gravity sand beds. The sand contents of the drums are readily cleaned by reversing the direction of the water ; while this is going on, a system of stirring arms is made to revolve and so stir up the sand that it is thoroughly washed. It is claimed that the filtering material never requires changing, being thoroughly cleaned in four minutes with so small a quantity of water as, in most cases, not exceeding $\frac{1}{3}$rd of 1 per cent. of the water passed through. When the water to be filtered is soft, lime-water is added to it in the mixing-tank, thus supplying carbonate of lime upon which the alumina can act. The chief advantages of this type of filter appear to be ease and simplicity in manipulation, small space occupied, rapidity of flow, and general independence of gradients, whereby loss of head to mains, so frequent a feature where gravity beds are in use, is avoided. For removing lead and iron from waters, these filters are well spoken of. The chief objection to this class of filter appears to be a risk of concretions and stoppages in mains arising from the use of coagulants like alumina ; we are not aware of this being a practical disability, but it is an argument which has been advanced against their use.

Another kind of filter which has come into prominent use, in recent years, is that known as the Candy Filter. In this system no chemical coagulants are used, no machinery is necessary, and there are no stirring arms or agitators to disturb the filtering material. The water to be purified is first saturated with air, forced into it under pressure, and then strained by passing it through a specially prepared filtering medium contained in cylindrical chambers or drums. The procedure claims to submit the water under purification to two treatments, namely, a primary oxidation of the organic matter in solution, followed by a mechanical straining equal to that obtained by passage through sand and gravel. The filtering medium is a patent preparation, but apparently of the nature of polarite or some mixture of the magnetic oxide of iron with alumina, silica, lime and carbon. Cleansing of this matrix is obtained by simply reversing the current of water through it, the amount used for this purpose being $\frac{1}{15}$th of 1 per cent. of the water filtered. Several installations have been put up in large towns and are successful, the procedure is effectual in removing iron and lead from waters, and the degree of bacterial purification is stated to average 93 per cent. Like the Bell filters, these are capable of delivering a rapid flow, and also, being capable of direct fitting to or on trunk mains, are able to filter water without appreciable loss of head.

What is known as the "Ferrochlore process" has been favourably spoken of. It is a method not unlike the rapid filtration already mentioned, and involves the use of two chemicals, an oxychloride of iron and chlorinated lime; a certain quantity of a mixture of these two solutions is added to the water, which is then delivered on to Howatson filters. The matrix of these filters is composed of specially crushed and sized silex, which is readily cleansed by the washing arrangements forming part of the filters. The ferrochlore is virtually free oxygen with oxides of chlorine and hydrated oxide of iron; this latter deposits on the surface of the filtering medium and forms a gelatinous film or membrane through which the water passes and becomes sterilised. The delivery of water treated by this method is much more rapid than that secured by ordinary sand and gravel beds.

Another method involving the use of chemicals before filtration is Anderson's. By this process, the water is passed through a wrought-iron cylinder, which contains a charge of metallic iron in small pieces, and is kept in continual slow rotation. The water is passed through at the rate of $\frac{1}{3}$rd to $\frac{1}{5}$th of the capacity of the cylinder per minute, and takes up from $\frac{1}{10}$th to $\frac{1}{5}$th of a grain of iron (ferrous hydrate) per gallon. On leaving the cylinder the water is passed into a settling-bed, and the ferrous hydrate, on exposure to the air, is quickly changed to ferric hydrate, which is precipitated in particles more or less coarse according to the nature of the water. Organic matter and micro-organisms become entangled in the precipitate and subside to the bottom of the settling-tank. This treated water can be now passed on to an ordinary sand filter, from which the delivery is more than doubled, or rather, the preliminary treatment reduces by more than half the area of filter surface required.

The foregoing methods are all designed for dealing with water in considerable quantities. Although it is customary for water supplied by public companies to be sufficiently purified before distribution, so as not to require filtration, yet circumstances exist in which domestic filtration is often a necessity. A number of substances have been suggested or used for this purpose. Among the more important of these are animal and vegetable charcoal, in granules or powder or made into blocks, or fine silica impregnated with charcoal (silicated carbon filters), hæmatite and magnetic iron

ores, the so-called magnetic carbide, spongy iron, manganic oxide, flannel, wool, sponges, porous sandstones (natural and artificial), &c.

Animal charcoal was formerly considered to be one of the best filtering materials. Later experiments, however, show that, although it possesses considerable oxidising powers on organic impurities present in water, it does not sterilise it, but, on the contrary, favours the development of micro-organisms in the water. It adds both phosphates and nitrates to water, which form a nutritive medium for bacteria. Water filtered through animal charcoal rapidly deteriorates as the charcoal yields up impurities to water, so that in many cases the water is more impure after it has passed through the filter than it was originally. While the charcoal attacks and oxidises the putrefactive organic matters in solution, it permits fresh or vital organic matter to pass through unchanged. On the whole, there is perhaps no material more unsuited or unsafe to use as a filtering medium for potable waters than animal charcoal. This cannot be too widely known, as it is still advocated in many standard works as being the best filtering material, notwithstanding the fact that recent methods of investigation have shown it to be the very reverse. The same remarks apply, in the main, to the greater number of the substances which have been enumerated above, the least objectionable being spongy iron and polarite.

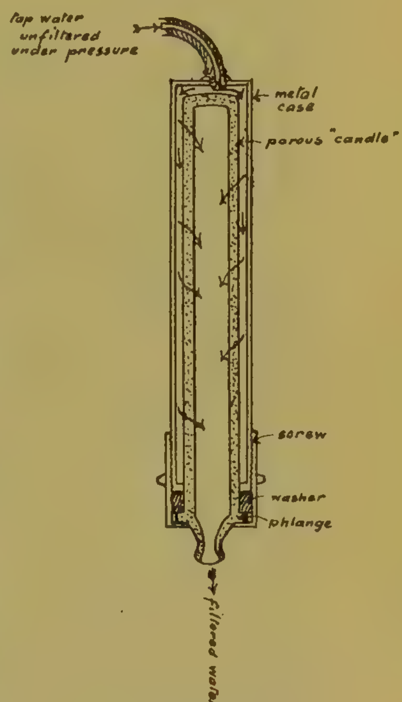


Fig. 4.—Modern Tube Filter fitted to Tap.

All recent work goes to show that no medium can be regarded as satisfactory for water filtration and for the construction of domestic filters which does not yield a germ-free filtrate. Judged by this standard, the only materials suited for filtration work are certain infusorial earths, clays, porcelain or patent combinations of porcelain with clay.* For this reason, modern domestic filters are made usually of one or other of these media; pure porcelain, owing to the closeness of its texture, is not of all-round domestic utility, delivering water but slowly; on the other hand, some of the infusorial earths are satisfactory in respect of the rapidity of flow through them, but not free from risk, owing to their softness and fragility. In our experience some of the best domestic filters are those made of judicious mixtures of porcelain with selected clays; these are moulded into cylinders or bougies, enclosed in metal jackets, and the water forced through them under pressure varying from 20 to 40 lbs. on the square inch. The usual type of these filters is shown in Fig. 4, where the filtering candle is attached to an ordinary tap and the water forced through the medium by the pressure of the water in the main. In the portable or detachable types, the water is placed under pressure by means of an attached pump and so forced through the filter. The action of these filters is merely to hold back the micro-organisms in the water, these being collected on the surface of the filter together with other suspended material. This fact leads to gradual clogging of the pores and a lessened flow of water through the filter; when the output becomes diminished, the candle needs cleaning by rubbing and brushing the

* Woodhead and Wood: "Report on the Relative Efficiency of Water Filters." *Brit. Med. Journal*, Nov. and Dec. 1894, also Jan. 1898.

surface under water. This process, in course of time, weakens the filter by removing some of its substance, but with care the life of an individual bougie or cylinder can be made to extend over a couple of years. A more serious risk attaching to the routine and unintelligent use of filters of this kind lies in the fact that in the course of time pathogenic bacteria, if present in the water under filtration, are capable of working their way into the pores of the medium and even through its mass so as to appear in the filtered water. In this passage through the actual filter they are helped by the pressure under which the water is forced through. The result of this is that one of these filters, if used for the filtration of dirty water, frequently becomes a seriously infected mass and a possible means of polluting an uninfected water passing through it. The rapidity with which bacteria can permeate the interstices of these filters varies with the fineness of their texture. Horrocks * has shown that while enteric fever bacilli are practically unable to get through the finest and closest porcelain, they can penetrate the lacunar spaces of the infusorial clays and the mixtures of clays with porcelain in from four to eleven days. As these coarser media constitute the material of which the greater number of these filters are made, we must for safety's sake sterilise these candles or cylinders every third day by boiling them in water. This is the regular practice in the army, where large numbers of these filters are in general use.

The experience of the army with filters of the candle type has further shown the need of safeguarding them from direct contact with muddy water ; if this is not done they clog up rapidly. A variety of devices have been tried to overcome this difficulty, with the result, it is found, that the most successful material for preliminary clarification of muddy water is coarse sponge closely packed. This removes much of the grosser suspended matter and so saves the filter proper. This principle is now adopted in all army filters with the best results. The sponges, of course, need systematic periodical cleansing and sterilisation, according to the character of the water passed through them. Unless the water has been very muddy, once a week is the army rule.

Sterilisation of Water by Heat.—There are three main ways in which heat can be applied for the purification of water ; these are distillation, boiling, and the employment of special apparatus working on the heat exchange principle.

Distillation is employed rarely on land, its applicability is limited practically to shipboard and to a few places abroad dependent upon sources of supply which are not only organically impure but also brackish. If efficiently carried out, distillation yields a pure and safe water, though the final product is often flat and dull owing to loss of dissolved gases ; one of the greatest of objections to distilled water is its indifferent storage qualities, particularly in hot countries.

Boiling is limited to the purification of water in small quantities, and, though ensuring the destruction of micro-organisms, presents the objections of being extravagant in fuel, makes the water flat and insipid, and leaves the finished article hot and of limited utility.

It is in order to overcome these objections, especially to retain the dissolved gases and deliver the water in a cool condition ready for drinking, that various *water sterilisers* have been brought forward. All these machines are designed on the principle of heat exchange, which, as applied to the purification of water, depends on the fact that, with a sufficient area of metallic

* Horrocks : "On the Protection from Water-borne Diseases afforded by Pasteur-Chamberland and Berkefeld Filters," *Brit. Med. Journal*, 1901, vol. i. p. 1471.

surface of good conducting capacity and sufficient time, a given quantity of hot liquid will yield nearly all its heat to an equal amount of similar but cold liquid. The more noteworthy apparatus of this kind are the special sterilisers designed by Vaillard-Desmaroux, Maiche, Hartmann, Lawrence, Waterhouse-Forbes, and Griffith. The first two named are French, while the third is of German origin; the Lawrence and the Griffith are English, while the other is American. In general design, the French and German apparatus are similar, and the following outline of the *Vaillard-Desmaroux* machine will convey a good idea of what the others are like. Mounted on wheels and with the appearance of a fire-engine, the machine consists of a boiler, two recuperators or exchange heaters, with temperature and pressure regulators. The boiler is composed of a number of tubes surrounded by a jacket containing half water and half steam. The exchange heaters are made of thin metallic plates rolled concentrically, leaving spaces between them about 40 cm. high and 5 mm. wide. These spaces are arranged so as to provide two distinct systems, one for the cold water flowing to the boiler, and the other for the water passing from the boiler to the exit. The temperature regulator consists of a cylinder containing a folded tube surrounded by petroleum, the water from the boiler circulates through the cylinder, and when the temperature is at the required height the folded tube expands, and forces up a rod which opens a valve placed in the supply-pipe, and permits the unsterilised water to enter the machine. A pressure regulator is placed at the entrance to the apparatus, and is intended to maintain an automatic pressure of 14 lbs. to the square inch. A second regulator placed at the exit is provided to maintain sufficient back pressure to prevent the formation of steam at the temperature of sterilisation. The larger machines deliver 110 gallons of sterile water per hour with the expenditure of only 2 to 4 lbs. of charcoal. The water retains its gases, and is quite cool at the exit. The machine can be arranged to work at any temperature between 100° C. and 120° C. The requisite head to cause the water to pass through the apparatus is obtained by means of a pump when pressure from a public supply is not available. The weight of these larger machines is 800 kilos.

The *Lawrence* apparatus is designed primarily as a water softener, but it also sterilises. It is much simpler than the continental machines and is made in two types, the domestic and the industrial. The feature of these sterilisers is the rapid deposition of temporary hard salts on plates or locators within the boiling chamber, and on the water reaching the bottom it circulates upwards to a heat exchanger, where it parts with nearly all its heat to the incoming cold water. The inner cylinder of the boiling vessel is removable, as are also the locators, so that they can be taken out at intervals and the deposit removed. These apparatus can be installed of any size, varying from a delivery of 40 to 50,000 gallons an hour. They are economical in fuel, soften and sterilise water, deliver it some 12° C. warmer than when it entered, and are simple to work.

The *Waterhouse-Forbes* and the *Griffith* water sterilisers are designed only to deal with small volumes of water. The former claims to deliver 25 gallons an hour; in our experience it has never yielded more than 18 gallons; apart from this low delivery, it is difficult to work, owing to the lamp being faulty. The Griffith machine is a decided advance; in the forms which have come under our notice it can deliver 60 gallons an hour readily, the outcoming water being 10° C. warmer than that going in. The fuel used is mineral oil, the expenditure working out at half a fluid ounce of oil for each gallon of treated water passed through the steriliser. The essential feature of this apparatus is the recognition of the fact that, for destruction of water-borne

pathogenic micro-organisms actual ebullition is unnecessary, but merely the momentary maintenance of the water at a temperature of 80° C. We have satisfied ourselves that this steriliser and also a larger type giving 300 gallons an hour yield a safe and sterile water; as they present many advantages for army work, their general design and management will be referred to again in the chapter dealing with Military Hygiene.*

Purification of Water by Chemicals.—Many of the processes suggested act by producing a precipitate which carries down suspended matter and micro-organisms. *Alum* has been used to purify water from suspended matters. It does this very effectually if there be calcium carbonate in the water; calcium sulphate is formed, and this and a bulky aluminium hydrate entangle the floating particles and sink to the bottom. The quantity of crystallised alum to be used should be about 6 grains per gallon. On similar lines *potassium permanganate* is added to water for purification purposes with the idea of suspended matters being carried down by the formation of a precipitate of manganic oxide. We have had considerable experience of this method and find the formation of this precipitate to be very uncertain. The treatment, however, has its value, acting mainly as an oxidising agent and germicide. It has been carried out for many years in India, where the water in wells and tanks has been regularly rendered rose-pink in colour by means of this re-agent in times of cholera. No precise quantity of the salt has been used, the rule being simply to add enough to make the water pink for half an hour or so. The results have been most satisfactory, cholera-tainted sources of water-supply being made relatively safe. The treatment gives no unpleasant taste to the water, the main objection is the colour, which is apt to offend the fastidious, prejudiced, and ignorant.

The chemical treatment of water in bulk has not received much attention in this country. The most recent, and probably the most extensive, trial of purification by simple chemicals was the treatment of the Lincoln water-supply in 1905 by sodium hypochlorite, containing 12 per cent. of free or available chlorine. This was added to the water in the reservoirs in the proportion of one part of the salt to 100,000 parts of the water, or 7 grains to each 10 gallons. As judged by the lessened number and improved quality of the bacteria in the water this was the smallest quantity giving satisfactory results. By giving a sufficiently small dose and a prolonged contact, dechlorination of the water seems to have been unnecessary, though the treated water is said to have had a mawkish or so-called "spent" taste. Lincoln at this time was afflicted with a serious outbreak of enteric fever, undoubtedly water-borne, but the result of this treatment of its water seems to have been distinctly successful.

Copper, as a means of purifying drinking water in bulk, has been brought forward very prominently in America,† especially in regard to the removal of algæ and confervoid growths in reservoirs, where their presence produces a bad odour and taste. The same problem has occurred in this country, and the employment of sulphate of copper for keeping down algæ and other vegetable growths in tanks, reservoirs, and sluices has been favourably reported on. Moore and Kellerman recommend the following dilutions, expressed as millions of water per one part of copper sulphate, for the destruction of the following commonly occurring organisms: *clathrocystis* 8, *oscillatoriæ* 5, *cœlosphorium* 3, and *microcystis* 1. The employment of such

* See articles in *Journ. Roy. Army Med. Corps*, vol. vii. pp. 218 and 226.

† Moore and Kellerman: Bulletin No. 64, Bureau of Plant Industry, U.S. Dep. of Agriculture, May 1904.

a salt as crystallised copper sulphate appears to be free from danger in these dilutions, as the copper is precipitated as a basic salt, the coagulating effect of which moreover often renders the finished water very clear and bright. Rideal reports that one part of the sulphate per million of water readily inhibits the growth of *spirogyra* in ponds and lakes. Our own experience has not been quite so favourable, as in attempting to keep down confervoid and other vegetable growths in tanks and ponds, by means of copper sulphate, any dilution over 1 in 500,000 seemed useless, and even then considerable care had to be taken to secure free diffusion of the re-agent. The simplest way is to tie the sulphate up in linen bags, attach these to punts or boats and tow them about the water to be treated. In these dilutions, we do not think copper sulphate added to water would deleteriously affect the consumer. Up to the time of writing, the Massachusetts State Board of Health had declined to sanction the employment of copper salts for drinking waters.

As a germicidal agent, copper needs to be added in considerable quantities, and the period of contact to be at least twenty-four hours. Fowler's * work on this point indicates that, in clear waters, 1 part of the sulphate per 60,000 of water is fairly efficient for removing sewage organisms, in turbid waters the amount must be doubled, and in foul waters the sulphate must be present to the extent of 1 in 10,000. This quantity gives no taste, but causes a bluish opalescence in the water. For routine consumption we consider these amounts of copper in a water to be highly objectionable. The effect of standing water in clean copper vessels appears to be negligible, at least so far as influencing the contained micro-organisms.

Chlorine, derived from the electrolysis of saline solutions, presents some promise as a means of purifying water in bulk. Rideal's experiments show that 0·6 part per million of available chlorine destroyed sewage bacteria in tap water in less than an hour, and that the residual available chlorine disappeared completely after some twenty hours' exposure in large tanks.† Similarly, confervæ and other microscopic plants are very susceptible to like amounts of available chlorine : desmids are more resistant and require at least 1 part per million of chlorine in excess of that immediately consumed by the water. What this immediate consumption chlorine figure is needs to be determined in each case, but the average of a number of waters coming under our notice shows it to be from 0·35 to 1·5 parts per million.

Ozone has been proposed for the sterilisation of water in bulk by Ohlmuller, Weyl, and others. Considerable installations for dealing with large volumes of water have been established in various continental cities, notably Lille and Berlin, but in this country the method has not been adopted other than tentatively. The reports generally are favourable, and possibly, with a more extended use of electricity, the application of ozone, so produced, to water purification may be further developed; but from our own inquiries into the practical working of the method, the main objections at present to it are difficulties about the dosage of ozone and the impossibility of establishing a control showing at each instant the efficacy of the treatment.

Of other chemicals suggested for the purification of water, a considerable number have been proposed.‡ The greater number are only applicable

* Fowler: "On the Value of Copper as a Means of purifying Drinking Water," *Journ. Roy. Army Med. Corps*, vol. v. p. 391.

† Rideal: *Journ. Roy. San. Institute*, 1904, vol. xxv. No. 3; also vol. xxvii. No. 10, p. 556.

‡ Macpherson: "The Purification of Water in Campaigns," *Public Health*, 1901, vol. xiii. p. 618.

to small quantities of water, but in spite of the unworkable nature of some of the re-agents, we confess to thinking that the feasibility of chemical treatment for sterilisation of small volumes of water by individuals is much greater than many think. Prejudice and unfamiliarity are the chief stumbling-blocks, but both of these, in time, will be overcome. We do not propose here to recapitulate the whole number of chemicals which have been suggested, but among the more promising are bromine, calcium hypochlorite, chlorine,* bi-sulphate of soda, and iodine. As the greater number of these have been experimented with for army needs and present a special interest to the soldier, a fuller consideration of their detailed application is given in chapter xx., on Military Hygiene.

EXAMINATION OF WATER FOR HYGIENIC PURPOSES.

The analysis of water for hygienic purposes has for its object the determination whether the water contains any substances, either suspended or dissolved, which are likely to be hurtful. There are some substances which we know are not likely to do any harm, such as carbonate of sodium, calcium, and magnesium in small quantities. Others are at once viewed with suspicion as indicating an animal origin, and, therefore, being probably derived from habitations or resorts of men or animals, or from decaying bodies. In other cases, substances in themselves harmless, such as nitrates, nitrites, and ammonia, are suspicious from implying the co-existence of, or the previous contamination of the water by, nitrogenous substances.

In addition to these purely chemical bodies, all waters contain a greater or less number of micro-organisms. The greater number of these are absolutely innocuous, while some others may be the essential causative agents of disease. Unfortunately the chemical conditions of a water sample are not always indicative of the extent and nature of its contained bacteria; for, at times, a water may be found to be chemically free from organic pollution, and yet contain a sufficient number of pathogenic micro-organisms to give rise to distinct disease processes in those consuming it; on the other hand, a water sample may, from chemical evidence, be deemed organically impure, and yet, by virtue of not containing any but non-pathogenic micro-organisms, be incapable of disease production. The difficulties, therefore, in the hygienic examination of a water sample are not inconsiderable, and a judgment will be only correctly arrived at from a collation of all the evidence, rather than from the results of one or two tests. The purely chemical evidence must be considered, as a rule, in conjunction with the bacteriological; for while the former, by informing us of the amount of organic matter present in water, places in our hands evidence of its dangerous or suspicious nature, in that it is either open to sources of infective disease (microbes), or that the presence of organic matter may perhaps render the water a most suitable medium for the growth of pathogenic organisms, should these gain access to it, it is only the bacteriological evidence which can actually say whether these sources of danger are truly absent or not. This statement of the case must not be taken to imply that mere chemical data are valueless as a means of forming a hygienic opinion; on the contrary, they constitute in the majority of cases practically the only facts upon which an opinion can be based, as, in the present state of our knowledge, exact bacteriological examinations of water occupy days or

* Nesfield: "A Chemical Method of Sterilising Water," *Public Health*, 1903, vol. xv. p. 601.

weeks, while a chemical analysis is rapidly performed. As, in the greater number of instances, a definite opinion is wanted without delay, a chemical analysis is still an important procedure, though necessarily incomplete unless supported by a biological investigation.

The examination of water, for hygienic purposes, may be conveniently considered under the general headings of (1) its physical characters, (2) its qualitative chemical examination, (3) its quantitative chemical analysis, (4) the microscopical examination of its suspended matters, and (5) its bacteriological examination. Preliminary to these discussions may be considered the proper precautions to be taken with regard to collection of samples and knowledge of its history, while as a necessary corollary and conclusion to them will follow a statement as to the interpretation of results.

Collection of Samples.—Great care must be taken that a fair sample of the water is collected in perfectly clean glass vessels (not in earthenware jars)—Winchester quarts, which hold about half a gallon, and can be obtained of most chemists, are most convenient; they should be repeatedly washed out with some of the water to be examined. In taking water from a stream or lake, the bottle ought to be plunged below the surface before it is filled. In drawing from a pipe a portion ought to be allowed to run away first, to get rid of any impurity in the pipe. In judging of a town supply, samples should be obtained direct from the mains, as well as from the houses. The bottle should be stoppered; a cork should be avoided, except in great emergency, but if used it should be quite new, well tied down, and sealed. No luting of any kind (such as linseed meal and the like) should be used.

For a complete sanitary investigation half a gallon is necessary, but with a litre or a couple of pints a fairly good examination can be made if more cannot be obtained. If a detailed mineral analysis is required (which will only be seldom) a gallon ought to be provided. It is always advisable to have a good supply in case of breakage or accident; two Winchester quarts of each sample will generally be found sufficient. The examination ought to be undertaken immediately after collection, if possible. If this cannot be done, then as short a time as may be should be allowed to elapse, for changes in the most important constituents take place with great rapidity. Pending examinations, it ought to be kept in a dark cool place.

The fullest information ought always to be furnished with the sample, the following being the most important particulars:—

(*a*) Source of the water, viz., from tanks or cisterns, main or house pipe, spring, river, stream, lake, or well.

(*b*) Position of source, strata so far as they are known.

(*c*) If a well; depth, diameter, strata through which sunk, whether imperviously steined in the upper part, and how far down. Total depth of well and depth of water to be both given. If the well be open, furnished with cover, or with a pump attached.

(*d*) Possibility of impurities reaching the water; distance of well from cesspools, drains, middens, manure heaps, stables, &c.; if drains or sewers discharge into streams or lakes; proximity of cultivated land.

(*e*) If a surface-water or rain-water, nature of collecting surface and conditions of storage.

(*f*) Meteorological conditions, with reference to recent drought or excessive rainfall.

(*g*) A statement of the existence of any disease supposed to be connected with the water-supply, or any other special reason for requiring analysis.

Any further information that can be obtained will always be useful. Each bottle should also be distinctly labelled, so as to correspond with the official letter or invoice.

When possible, it is most desirable that the medical officer or analyst should visit the locality itself whence the water is obtained; in this way he may obtain information which might otherwise escape him. If the analysis can be made immediately on the spot, it will be all the more valuable.

Physical Examination.—This will have reference to the following points, and affords, at times, valuable preliminary information as to any given sample.

Colour.—This may be judged of by allowing any sediment to settle, and then pouring off the supernatant water into a tall glass placed upon a piece of white paper. Or a horizontal tube of colourless glass with glass ends may be used. The stratum should be of sufficient thickness, if possible *two* or *three* feet, but a fair idea of the colour may be obtained with 18 inches or even a foot.

Perfectly pure water has a bluish tint, but most ordinary waters have either a greyish, greenish, yellow, or brown appearance. The best samples are those coloured bluish or greyish. Green waters owe their colour to vegetable matter, chiefly unicellular *algæ*, and are usually harmless. A yellow or brown colour is often due to animal organic matter, chiefly sewage. It is sometimes, however, owing to vegetable matter, such as peat, and under these circumstances it is not generally hurtful. It may also be caused by salts of iron, although in most cases the iron is precipitated as ferric oxide in the sediment.

Clearness.—The presence or absence of turbidity may be judged of in the same way as the colour, only the water should be shaken up, so as to distribute the suspended matter and simulate its condition when drawn. The depth necessary to obscure printed matter may be used as a measure.

Taste and *Smell* are uncertain indications. Any badly tasting or smelling water should be rejected or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as *lemna* and *pistia*, give a bitter taste; but most growing plants have no taste. Dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. Iron, when present to the extent of $\frac{1}{5}$th of a grain to the gallon, and salt, to the extent of 75 grains to the gallon, are detectable by taste.

Although the *physical characters* give only an imperfect idea of the value of a water, they are yet important when no further examination can be made. If a water be colourless, clear, free from suspended matter, of a brilliant (or adamantine) lustre, devoid of smell or taste, except such as is recognised to be the characteristic of good potable water, we shall in the large majority of cases be justified in pronouncing it a good and wholesome water; whilst, according as it deviates from these characters, we shall be proportionately justified in regarding it with suspicion. Suspended matter is probably the most dangerous, and, when in the form of disease-causing micro-organisms, exists without revealing itself by any visible turbidity, or even to any ordinary microscopic examination. Bacteria can only be detected by biological examination; nor must we shut our eyes to the possibility of hurtful dissolved substances, so that when our opinion of a

water is based only on its physical characters, the fact ought to be duly recorded.

Qualitative Chemical Examination of Water.—The sample may be either at once treated, or, in the case of some constituents, a portion of it should be concentrated by evaporation.

In water not concentrated the following qualitative reactions may be noted.

Lime.—The addition of oxalate of ammonium gives a turbidity with about 9 parts per 100,000, and a considerable white precipitate with anything over 20 parts per 100,000.

Chlorine.—With nitrate of silver and dilute nitric acid the presence of 1·5 parts per 100,000 gives a haze; 6 parts per 100,000 causes a marked white turbidity: this tends to darken on standing.

Sulphates.—The presence of these salts is shown by a white precipitate on adding a few drops of chloride of barium solution and some dilute hydrochloric acid.

Nitrates.—Add a few drops of brucine solution, shake, then pour gently down the side of the test-tube a little pure sulphuric acid so as to form a layer under the mixed water and brucine solution. The presence of 0·7 part of nitric acid in 100,000 of the water will cause a pink and yellow zone to form at the junction of the acid with the water. This test is unreliable in the presence of nitrous acid, but by adding a few drops of sulphuric acid with some crystals of pure urea to 100 c.c. of the water and allowing it to stand for an hour the nitrous acid will be destroyed. The brucine test may be now applied for detection of nitrates which are unaffected.

Nitrites.—If these are present, the addition of iodide of potassium and starch solution and dilute sulphuric acid at once gives a blue colour. Another delicate test is the adding of a few drops of a solution of metaphenylenediamine and dilute sulphuric acid which gives a yellow colour, more or less immediately.

Ammonia.—A drop of Nessler's solution will give a yellow to brown colour in the presence of very small quantities of ammonia.

Iron.—Either the red or yellow prussiates of potash with dilute hydrochloric acid give a blue colour with iron salts; the red prussiate with ferrous and the yellow prussiate with ferric salts.

Lead or Copper.—In the presence of these metals, ammonium sulphide solution gives a dark colour which is not cleared up by hydrochloric acid.

Lead.—A few small crystals of potassium bichromate give an immediate turbidity in the presence of lead to the extent of $\frac{1}{10}$th of a grain per gallon; $\frac{1}{20}$th of a grain per gallon reacts in a minute, and $\frac{1}{50}$th of a grain per gallon after half an hour.

Zinc can be detected, if present, by rendering the water slightly ammoniacal, boiling and then filtering; a few drops of potassium ferrocyanide produce a haze if zinc be present.

In water concentrated to $\frac{1}{50}$th, the following qualitative reactions may be made:—

Magnesia.—Precipitate any lime present by oxalate of ammonium, filter, then add a few drops of phosphate of sodium, of chloride of ammonium, and liquor ammoniæ. If magnesia be present, crystals of the triple phosphate will precipitate out in twenty-four hours.

Phosphates.—Add some dilute nitric acid, stir with a glass rod, and then add an excess of molybdate of ammonium and boil. If phosphates are present, a yellow colour will form.

In the preceding qualitative tests, all the re-agents may be deemed to be

saturated solutions, except the dilute acids, Nessler's re-agent, brucine solution, iodide of potassium and starch solution and the meta-phenylenediamine solution.

The dilute acids are best prepared by adding 1 part of strong acid to 9 of distilled water.

The Nessler's re-agent will be more fully explained later on (page 87).

The brucine solution is made by dissolving 1 gramme of brucine in 1 litre of distilled water.

The potassic iodide and starch solution is made by boiling 20 grammes of starch intimately mixed with half a litre of distilled water, filtering when cold, and adding 1 gramme of potassium iodide.

The meta-phenylenediamine solution is described when explaining the quantitative estimation of nitrites.

Inferences from the Qualitative Tests.—Sometimes no time can be given for quantitative determinations, and the qualitative tests are the only means available by which the questions so constantly put, whether a water is wholesome or not, can be in some degree answered.

If chlorine be present in considerable quantity, it either comes from strata containing chloride of sodium or calcium, from impregnation with sea-water, or from admixture of liquid excreta of men and animals. In the first case the water is often also alkaline, from sodium carbonate; there is an absence, or nearly so, of oxidised organic matters, as indicated by nitric and nitrous acids and ammonia; there is often much sulphuric acid. These characters are common in deep-well waters. If it be from calcium chloride, there is a large precipitate with ammonium oxalate after boiling. If the chlorine be from impregnation with sea-water, it is often in very large quantity; there is much magnesia, and little evidence of oxidised products from organic matters. If from sewage, the chlorine is marked, and there is coincident evidence of nitric and nitrous acids and ammonia, and sometimes phosphoric acid.

Ammonia is almost always present in very small quantity, but if it be in large enough amount to be detected without distillation it is suspicious. If nitrates, &c., be also present, it is likely to be from animal substances, excreta, &c. Nitrates and nitrites indicate previously existing organic matters, probably animal, such as excreta, remains of animals, &c.; but nitrates may also arise from vegetable matter, although this is probably less usual. If nitrites largely exist, it is generally supposed that the contamination is recent. The coincidence of ammonia, and of chlorine in some quantity, would be in favour of an animal origin. If a water gives the test of nitric acid, but not nitrous acid, and very little ammonia, either potassium, sodium, or calcium nitrate is present, derived from soil impregnated with animal substances at some anterior date. Phosphates, if present in any marked quantity, are suggestive of sewage pollution. Lime in large quantity indicates calcium carbonate, if boiling removes the lime; sulphate, chloride or nitrate, if boiling has little effect. Testing for calcium carbonate is important in connection with purification with alum. Sulphuric acid in large quantity, with little lime, indicates sulphate of sodium, and usually much chloride and carbonate of sodium are also present, and on evaporation the water is alkaline. Large evidence of nitric acid, with little evidence of organic matter, indicates old contamination; if the organic matter be large, and especially if there be nitrous acid as well as nitric present, the impregnation is recent.

To the above qualitative tests should, of course, be added the physical characters, which would to some considerable extent influence the con-

clusions to be drawn. When possible, the microscopic appearances ought also to be carefully noted, as the presence of such substances as epithelium, house refuse, &c., will sometimes justify us in condemning a water which may appear chemically only suspicious.

A water containing in appreciable quantity any metal (except iron), other than the alkaline and earthy metals, is to be condemned.

The Quantitative Analysis of Water.—The discrepancies which are sometimes found in the consecutive analyses, or in analyses by two observers of the same water, probably often arise from the difficulty of always separating the suspended matters. Consequently two samples, apparently similar, may in reality contain variable quantities of suspended matters, which affect the determination of the solids, or influence other tests.

To avoid this source of fallacy, if the water be sedimentous, the portion to be examined for solids should be placed in a well-stoppered bottle in a dark place for twenty-four or forty-eight hours, until all sediment has subsided, and the clear water should be then siphoned off. If the sediment is too fine to subside, the water must be filtered through paper (previously well washed with weak hydrochloric acid, and then with distilled water, and then dried), but if possible filtration should be avoided.

Of the solids in water some are mineral, and derived from the mineral constituents of the soil, such as lime, magnesia, part in combination with chlorine, and part with sulphuric, carbonic, and silicic acids; others are also inorganic, but are derived from the remains of animals or vegetables, by oxidation or solution, or from the atmosphere, these solids include ammonia salts, nitrates, nitrites, chlorides, sulphates and phosphates. Other constituents, derived from numerous sources, are vegetable or animal matters, which are usually unstable, and are undergoing disintegration and oxidation. They may be nitrogenous or not. The composition of these substances is doubtless extremely various; the determination of the total quantity is difficult; the separation of the different kinds from each other, at present, impossible.

The quantitative processes which appear, in a hygienic sense, to be most useful, are the determinations of the total and volatile solids, the chlorine, the nitrogen in ammonium compounds and in organic matter, the nitrogen as nitrates and nitrites, the oxygen consuming power, the dissolved oxygen and carbonic acid, the total and fixed hardness and the poisonous metals.

The Principles of Volumetric Analysis.—The main principle upon which volumetric quantitative analysis depends is, that in order to convert a compound *a*, existing in solution, into some other *b*, there is required a quantity of re-agent *c* proportional to the quantity of *a*. If, therefore, we know *c*, as well as its strength, we can calculate *a*; in other words, a volumetric quantitative analysis is the submission of the substance, to be estimated to certain characteristic reactions, employing for such reactions solutions of known strength; and, from the volume of solution necessary for the production of the reaction, determining the weight of the substance to be estimated, by the application of the known laws of chemical equivalence. The process of adding the reagent from a graduated measure is called *titration*.

For the accurate performance of titration, the following conditions must be fulfilled:—

1. The substance under examination must exist in clear solution in a liquid miscible with the liquid re-agent: for this purpose aqueous solutions are the best.

2. The operator must thoroughly understand the relationship between measures of weight and volume.

3. The apparatus employed must be accurately graduated.

4. The titrating re-agent must be a solution of known strength, that is, a so-called standard solution.

5. We need a special re-agent (indicator) in order to ascertain when sufficient quantity of the standard solution *c* has been added to effect the required reaction, or the complete transformation of *a* into *b*.

To carry out any quantitative analysis, the first essential is the thorough comprehension of the simple relationship between liquids and solids. In the following pages of this work, owing to its uniformity and simplicity in all analytical methods, the metric system of weights and measures will, as far as possible, be employed. Although tables of the various metric weights and measures are given in the *Appendix*, it may not be out of place here to emphasise the fact that a cube of distilled water, at its temperature of greatest density, namely at 4° C. or 39°·2 F., whose side measures 1 decimetre, has exactly the weight of 1 kilogramme, or 1000 grammes, and occupies the volume of 1 litre or 1000 cubic centimetres. In other words, 1 cubic centimetre, as a measure of volume, equals or corresponds to 1 gramme as a measure of weight, and that :—

x Grammes	of a substance	dissolved in	10	cubic centimetres	of water are	*x*	parts in	10
x „	„	„	100	„	„	*x*	„	100
x „	„	„	1000	„	„ (1 litre)	*x*	„	1,000
x Decigrammes	„	„	„	„	„ „	*x*	„	10,000
x Centigrammes	„	„	„	„	„ „	*x*	„	100,000
x Milligrammes	„	„	„	„	„ „	*x*	„	1,000,000
x „	„	„	100	„	„ of water	*x*	„	100,000
x „	„	„	10	„	„ „	*x*	„	10,000
x „	„	„	1	„	„	*x*	„	1,000

It is most usual in this country and on the Continent to express the results of a quantitative analysis of water as parts per 100,000, or centigrammes per litre, or milligrammes per 100 cubic centimetres. Some analysts express their results as parts per million, or milligrammes per litre. The statement of a ratio in parts per 100,000 will be adopted in the following analytical processes, while, for the sake of brevity, the term " cubic centimetre " will be written as c.c.

Occasionally, the expression " grains per gallon " is met with in English analysis. This is equivalent to parts per 70,000, as one gallon of water at 39°·2 F. or 4° C. weighs 10 lbs., or 70,000 grains. The conversion of parts per 100,000 to grains per gallon is, of course, readily performed by multiplying by seven-tenths, or by 0·7, and from grains per gallon to parts per 100,000 by multiplying by 10 and dividing by 7.

The apparatus specially needed for making an ordinary quantitative analysis of water includes :—

A pair of balances and weights, according to the metric system. In these sets of weights, the larger ones represent grammes, the next in size decigrammes, and the next centigrammes. Small forceps are used for picking up and applying these weights to the pans of the balance. The milligrammes are added by shifting a little piece of bent wire along the crossbeam of the balance, which has on it ten markings, numbered from 1 to 10, on either side of the pivot.

A platinum dish, capable of holding 200 c.c. of water.

One or more shallow *porcelain evaporating dishes*, capable of holding 300 c.c.

A small *porcelain crucible*, with lid, for igniting residues.

A pestle and mortar, for powdering re-agents previous to solution.
One or more *retorts*, or boiling flasks.
A Graham's, or Liebig's *condenser*.
Six *Nessler glasses*, each capable of holding 150 c.c.
Glass *stirring-rods*.
Two glass-stoppered bottles, each capable of holding 250 c.c.
Glass *funnels* for filtering.
A packet of Swedish *filter-papers*.
A dozen *test-tubes*, with stand, cleaner, and holder.
A measuring flask, to hold at least 1 litre and graduated in c.c.
Glass *burettes*, or graduated tubes, holding 20 c.c., and graduated in c.c. and tenths of a c.c. One of these should be mounted on a wooden stand, and be provided with a stopper at the top, and fitted with a stop-cock at the bottom.
A glass *pipette*, graduated to deliver 10, 20, 50, or 100 c.c.
An iron tripod.
One or more triangles of iron wire, covered with pipeclay.
A pair of small crucible tongs.
A long thermometer, graduated in either Centigrade or Fahrenheit degrees.

The " Standard Solutions " required in a volumetric quantitative analysis are solutions of definite strength, made by dissolving a given weight of a re-agent, in grammes, in a definite volume of distilled water in cubic centimetres (or in grains or fluid grains). Normal solutions are made by dissolving the hydrogen equivalent weight of the re-agent in grammes, in 1000 c.c. (1 litre) of distilled water at 16° C. The following abbreviations are often used to express the strength of normal solutions, and their subdivisions :—

N	= a normal solution having	1	hydrogen equivalent in grammes per litre.		
$\frac{N}{2}$	= a semi-normal ,,	$\frac{1}{2}$	,,	,,	,,
$\frac{N}{10}$	= a deci-normal ,,	$\frac{1}{10}$	,,	,,	,,
$\frac{N}{20}$	= a viginti-normal ,,	$\frac{1}{20}$	,,	,,	,,
$\frac{N}{100}$	= a centi-normal ,,	$\frac{1}{100}$	,,	,,	,,
$\frac{N}{1000}$	= a milli-normal ,,	$\frac{1}{1000}$	,,	,,	,,

Occasionally, in making normal solutions, the equivalent hydrogen weight of a re-agent cannot be taken, but its particular weight in a particular reaction in a given analysis has to be regarded. For instance, when using a solution of potassic permanganate, as an oxidising agent, having the chemical formula $KMnO_4$, and the molecular weight of 158, and yielding five volumes of oxygen in a particular reaction, its normal solution is made by dissolving one-fifth of its molecular weight, $\frac{158}{5}$, or 31·6 grammes in a litre of water. In other instances, when the hydrogen equivalent weight of a substance is not identical with the atomic or molecular weight, the amount taken is that of the equivalent hydrogen weight. Thus oxalic acid, $C_2H_2O_4.2H_2O$, with an atomic weight of 126, is a bivalent substance, and its equivalent weight is one-half of its atomic weight; consequently, a normal solution of oxalic acid would be made by dissolving 63 grammes of the crystallised acid in 1 litre of distilled water. Similarly, phosphoric acid, which is a trivalent substance, would require, for the preparation of a normal solution of sodic phosphate, $Na_2HPO_4.12H_2O$, one-third of

its molecular weight $\frac{358}{3}$, or 119·3 grammes, being dissolved in 1 litre of distilled water.

In some other cases, standard solutions cannot be prepared directly, because the substance to be dissolved cannot be obtained sufficiently pure to make an accurate solution. Hence we must have recourse to an indirect method. Thus, if it were wanted to make a solution of potash-lye, containing 56 grammes of potassium hydroxide to the litre, we could not make it by simply weighing out 56 grammes of potassium hydroxide and dissolving it in a litre of water, because the alkali can never be procured absolutely pure. But if, say, 65 grammes be dissolved and slowly diluted down until 10 c.c. exactly neutralise 10 c.c. of an oxalic acid solution made by dissolving 63 grammes of $C_2H_2O_4.2H_2O$ in a litre, we then get a solution of the potassium hydroxide of the strength of 56 grammes per litre, because from their molecular weights we know 63 grammes oxalic acid exactly neutralise 56 grammes of potassium hydroxide.

An "indicator" is a substance added to enable us to ascertain by a change of colour, or other equally marked effect, the exact point at which a given reaction is complete. The chief indicators employed are as follows :—

(*a*) *Solution of litmus*, which turns red with acids and blue with alkalies. This solution needs to be made from the best litmus, by boiling in water for eight minutes, then neutralising the alkaline carbonate which it usually contains with HCl, until the wine-red colour remains even on further boiling. The solution is then cooled and an equal volume of strong alcohol added. The stock solution should be kept in a bottle with a delivery pipette inserted through the cork.

(*b*) *Alcoholic solution of phenol-phthalein*, made by dissolving 5 grammes with the aid of 25 c.c. of spirit of wine, in 500 c.c. of distilled water. This solution is colourless with acids, but becomes red with alkalies.

(*c*) *Starch mucilage*, which turns blue in the presence of free iodine.

(*d*) *Saturated solution of potassium chromate*, which gives a red colour with nitrate of silver, but not until all the halogen present has entirely combined with the silver.

(*e*) *Saturated solution of potassium ferricyanide*, which ceases to give a blue colour when any iron present has been fully raised to the ferric state.

(*f*) *Methyl orange* is useful for standardising any of the mineral acids by means of pure sodic carbonate in the cold, the liberated carbonic acid having practically no effect. A convenient strength is 1 gramme of the powder in a litre of distilled water ; a single drop of the liquid is sufficient for 100 c.c. of any colourless solution—the colour being faint yellow if alkaline, and pink if acid.

Determination of the Dissolved Solids.—The remark already made about suspended matters must be attended to ; if possible, obtain a clear water by subsidence rather than by filtering through paper. The solids are determined by evaporation, and are generally spoken of as the total, fixed, and volatile solids.

Total Solids.—If very good balances are available, 200 c.c. of the water are sufficient ; if the balances are inferior, 500 or 1000 c.c. of the water sample must be taken, then evaporate to dryness with a moderate heat, taking care that the water does not boil, else there may be loss from spurting. If the smaller quantity to be taken, the whole evaporation may be conducted in one vessel (of platinum, if possible) ; but if the larger amount must be used the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids

shall remain encrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in air, water, or steam bath, at 212° F. (100° C.), then remove all traces of moisture by heating in the hot-air chamber to 220° F. and cool in the desiccator. Weigh as soon as the crucible is cold, as the dried mass may be hygroscopic. It may be necessary to replace it in the bath and weigh again after an interval of half an hour. If there is no material difference the drying is completed.

The determination of the total solids is an important point, and should be carefully done. It gives a control over the other quantitative determinations, and if erroneous may make the other conclusions wrong.

Fixed Solids.—Incinerate the dried solids at as low a heat as possible; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitric oxide which may be given off.

Volatile Solids.—The loss on ignition may be stated as "volatile substances." It consists of destructible organic matters, nitrates, nitrites, ammoniacal salts, combined water, combined carbonic acid, and sometimes chlorides. The variableness of the composition of the "volatile substances" has led to the disuse of the process by ignition as too uncertain. Combined with other evidence it gives, however, some useful indications.

The combined CO_2 can be partly restored after incineration by adding a few drops of a saturated solution of carbonate of ammonia, then drying and driving off the excess of ammonia.

The amounts of total solids in ordinary water samples vary from 3 or 4 to 50 or 60 parts per 100,000. Of these not more than 1·5 per 100,000 should be volatile or lost on ignition.

Determination of the Chlorine.—For this purpose two solutions are required:—

(1) *A solution of Potassium Monochromate*, made by dissolving 50 grammes of the salt in a litre of distilled water. Nitrate of silver is added until a permanent red precipitate is formed, which is allowed to settle and the clear liquid decanted off.

(2) *A deci-normal standard solution of Silver Nitrate*, made by dissolving 17 grammes of $AgNO_3$ (molecular weight being 170) in a litre of distilled water. This will be equivalent to one-tenth of the atomic weight of chlorine (35·5) or 3·55 grammes of chlorine, and 1 c.c. of this solution will equal 3·55 mgms. of chlorine.

The process consists in taking 250 c.c. of the water sample, placing them in a white porcelain dish, and rendering them of a distinct yellow colour by means of two or more drops of the potassium chromate solution. From a burette, run in drop by drop some of the $\frac{N}{10}$ silver nitrate solution, stirring after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. As each c.c. of the silver solution equals 3·55 mgms. of chlorine, the number of c.c. used indicates the mgms. of chlorine in 250 c.c. of the water, that is, parts per 250,000, and that divided by 2·5 or multiplied by 0·4 will give parts of chlorine per 100,000.

Example.—In 250 c.c. of water, rendered yellow with potassium chromate, 1·5 c.c. of silver solution gave a permanent red tint; then—

$$\frac{1·5 \times 3·55}{2·5} = 2·13 \text{ parts of chlorine per } 100,000.$$

The purest water, as a rule, contains less than 1·5 parts of chlorine per 100,000. An increase may be due to sea-water, percolation through salt-bearing strata, to sewage, or other impurities. Some deep wells often contain large quantities of chlorides; but generally an excessive presence of chlorine is a reason for suspicion unless a satisfactory explanation of its presence is obtainable.

Determination of the Hardness.—Clark's very useful soap test offers a ready mode of determining this in a manner quite sufficient for hygienic and economic purposes. Soap is an alkaline oleate, resulting from the combination of an alkali with one or more of the fatty acids, *i.e.*, oleic, stearic, or palmitic acids. When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down or used up. The hardness of a water depends upon the presence in it of more or less of these earthy bases, and the more they are present the greater will be the expenditure of soap to make a lather. Free carbonic acid has a similar effect. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There are, however, one or two points which render the method less certain. One of these is that, in the case of magnesia, there is a tendency to form double salts, so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with the soap solution, two equivalents of the acid unite with one of soap.

A certain amount of the hardness of a water is removed by boiling, hence it is usual to speak of the hardness present before boiling as total hardness, that remaining after boiling as fixed or permanent hardness, and that which has been dissipated by the boiling as temporary hardness.

The total hardness in most drinking waters is caused by salts of calcium and magnesium with some free carbonic acid. Hence waters from the chalk, oolite, limestone, dolomite, and new red sandstone are apt to furnish the greatest degrees of hardness. Rain-water being free from these salts, is usually very soft. Many of the salts contributing to the total hardness are held in solution by carbonic acid, which when the water is boiled is dissipated, causing these salts to fall to the bottom or form incrustations on the sides of the containing vessel as insoluble salts. The chief of these are carbonates and sulphates of lime and magnesium with salts of silica, alumina, and iron when these are present.

The permanent hardness, or what still remains in solution, consists mainly of some sulphates, chlorides, and nitrates of calcium and magnesium, with a little iron and alumina.

The amount of hardness is, for convenience, usually expressed either in degrees of the metrical scale (parts per 100,000) or in grains per gallon of calcium carbonate, each grain representing 1 degree of hardness on the scale proposed by Clark. Of course it is understood that the hardness depends on various constituents, but in England is equivalent to so much calcium carbonate. In France, the hardness is also expressed as calcium carbonate, but only on the metrical scale, that is, in parts per 100,000. In Germany, the hardness is always expressed as so much lime, CaO, per 100,000. In cases of comparative analysis, therefore, 1 metrical French or English degree of hardness equals 0·56 German degree, and 1 degree of

hardness on Clark's scale equals 0·39 German degree and 0·7 French or English metrical degree.

The Soap solution for the estimation of hardness is best made by thoroughly dissolving by stirring and warming some soft soap in a mixture of 4 parts methylated spirits to 6 of distilled water and then filtering. This solution of soap should be standardised, that is, diluted or strengthened as the case may be, so that 2·2 c.c. of it exactly give a permanent lather when shaken up with 50 c.c. of a solution of nitrate of barium. Barium nitrate, $Ba(NO_3)_2$, has a molecular weight ratio to calcium carbonate, $CaCO_3$, of as 261 is to 100, and if 0·261 gramme of barium nitrate be dissolved in a litre of distilled water, that solution equals 0·1 gramme of calcium carbonate, and 50 c.c. of the same solution equals 5 mgms. of calcium carbonate. Now, if the soap solution be so made that 2·2 c.c. of it give a lather with 50 c.c. of the above barium nitrate solution, after deducting 0·2 c.c. for the amount of soap solution necessary to give a lather with 50 c.c. of distilled water, we get 2 c.c. of the soap solution to equal 50 c.c. of a barium nitrate solution, which again is equivalent to 5 mgms. of calcium carbonate, hence each c.c. of the soap solution equals 2·5 mgms. of calcium carbonate. Say, for instance, 35 c.c. of soap solution of unknown strength have been made, and, on being standardised with 50 c.c. of the barium nitrate solution, it is found that 1 c.c. gives a lather in place of 2·2. c.c. being so required. Then as $1 : 2{\cdot}2 :: 30 : x = 66$; that is, 30 c.c. of it must be diluted up to 66 c.c. to give a soap solution, of which 1 c.c. shall exactly equal 2·5 mgms. of calcium carbonate. Of course, if the soap solution be found too weak it must be proportionately fortified with more soap until 2·2 c.c. exactly give a lather with 50 c.c. of the 0·261 barium nitrate solution.

In some analytical statements the term " measure " is used to avoid the repetition of the expression " tenth of a cubic centimetre." If so employed, one measure of soap solution may be taken, therefore, as precipitating 0·25 of a milligramme of calcium carbonate.

Total Hardness.—Take 50 c.c. of the sample and place in a stoppered shaking-bottle. From a burette run in sufficient of the soap solution until, on being briskly shaken, the contents of the bottle give only a faint dull sound with the formation of a quarter-inch of fine uniform lather. This lather should show an unbroken surface after standing five minutes.

Example.—Suppose the addition of 2·4 c.c. of the soap solution have produced the necessary sound and lather. Deducting 0·2 c.c. as being necessary for the production of a lather in 50 c.c. of the purest water, we get 2·2 c.c. of the soap solution required by 50 c.c. of the water sample, or 4·4 necessary for 100 c.c. Each of these c.c. equals 2·5 mgms. of calcium carbonate: hence $4{\cdot}4 \times 2{\cdot}5 = 11$ mgms. of calcium carbonate in 100 c.c. of the water, representing a total hardness of 11 parts per 100,000, that is, 11 degrees of hardness on the metrical scale. Expressed as grains of calcium carbonate per gallon, or degrees of hardness on Clark's scale, we get $11 \times 0{\cdot}7 = 7{\cdot}7$ grains per gallon of $CaCO_3$.

When the total hardness exceeds 20° on the metrical scale, an over-estimation may be made as the excess of calcium and magnesium salts interfere with the formation of the characteristic lather. In these cases, it is better to dilute 25 c.c. of the sample with 25 c.c. of distilled water; proceed as explained, when the net amount of soap solution used will indicate the hardness in parts per 100,000. If magnesium salts are present the lather will often be brown in colour and break very easily; under these conditions it is advisable to dilute the water and shake very carefully.

The Permanent or Fixed Hardness.—Take 100 c.c. of the water and 100 c.c. of distilled water; boil in a flask briskly for half an hour, allow it to cool down to 60° F. (15°·5 C.) in the vessel, which should be corked, and then make up the bulk to exactly 100 c.c. with distilled water;

determine the hardness in 50 c.c. If distilled water is not procurable, then boil 200 c.c. down to 100; take half the remainder (= 100 of unboiled water) and determine the hardness.

By boiling, all carbonic acid is driven off; all calcium carbonate, except a small quantity, is thrown down; the calcium sulphate and chloride are not affected if the evaporation is not carried too far; some of the magnesium carbonate at first thrown down is redissolved as the water cools.

Example.—Say 50 c.c. of the water thus treated required 1·6 c.c. of soap solution. Deducting 0·2 c.c. for lather, we get 1·4 c.c., and $1 \cdot 4 \times 2 \cdot 5 \times 2 = 7$ mgms. of calcium carbonate present in 100 c.c. of the water, and these 7 mgms. $CaCO_3$ represent the permanent hardness of 100 c.c. (100,000 mgms.) of the water sample, or, in other words, 7 parts per 100,000 of permanent hardness, or 4·9 grains per gallon.

Removable Hardness.—The difference between the total and permanent hardness is the temporary or removable hardness, which in the example would be $11 - 7 = 4$ degrees of the metrical scale, and $7 \cdot 7 - 4 \cdot 9 = 2 \cdot 8$ degrees of Clark's scale.

The total hardness of a water should not exceed 30 parts per 100,000, otherwise it is unsuitable for domestic purposes. What are called hard waters vary from 20 to 30 degrees on the metrical scale; a soft water from 8 to 15; while a very soft water may contain up to 6 or 8.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts—viz., calcium sulphate and chloride and the magnesium salts. The greater the permanent hardness, the more objectionable is the water. The permanent hardness of a good water should not, if possible, be greater than about 5 degrees of the metrical scale, equal to 3 degrees or 4 degrees of Clark's scale.

Determination of Organic Matter in a Water Sample.—It has already been explained how organic matter is constantly gaining access to water by many channels, and that following in the wake of this organic pollution of drinking waters come widespread evil consequences in the form of various kinds of disease. By organic pollution is meant the fouling of water by both animal and vegetable material, together with the products of their decomposition; and although the relative significance of, and danger from, animal contamination is usually greater than that from vegetable impurities, still the recognition of either or both forms of organic matter constitutes an important procedure in the analysis of water for health purposes. Unfortunately there is no single analytical process which, by itself, can give us any closely proximate estimation of this organic matter. Recognising the fact that all organic matter, whether of animal or vegetable origin, exhibits a natural tendency to resolve itself, under suitable conditions of temperature and moisture, into simple parts, such as carbonic acid, ammonia, and oxidised salts of nitrogen, such as nitrites and nitrates, the most reliable processes for the determination of organic matter in water are only indirect ones, being practically estimations of either carbonic acid, ammonia, or nitrogen produced by its decomposition.

In addition to these, the chemical processes for the determination of organic matter in water include others whose object is essentially to detect the presence of other chemical constituents which, by entering into the composition of organic bodies, gain access to water along with it, that is, chlorides, sulphates, and phosphates. To these may be added estimations of the affinity of the particular sample for oxygen.

Possibly one of the most ingenious processes proposed to determine the organic matter in water is that devised by Frankland; but, owing to the need of special apparatus and of great technical skill to avoid errors in its

conduction, it is quite unsuited for the requirements of the greater number of those engaged in public health work. By this method, a measured volume of water is evaporated to a solid residue, and this, after collection in a hard glass combustion tube, is mixed with oxide of copper, and burnt in a furnace. The oxide of copper parts with its oxygen to the organic matter, which is completely burnt, and the resulting carbonic acid and nitrogen collected, measured, and returned in terms of "organic carbon" and "organic nitrogen."

By this process the purity of water is judged from a consideration of the actual amounts of organic carbon and organic nitrogen present, and their relative proportions to each other. A low quantity of each and a small relative amount of organic nitrogen is deemed favourable to the water. Much carbon and little nitrogen is indicative of vegetable pollution, whereas, on the other hand, the nearer the amount of nitrogen approximates to that of carbon the greater is the indication of the pollution being of animal origin.

More practical than, if not actually superior to, Frankland's is the method proposed by Wanklyn and Chapman, in which two kinds of ammonia are recognised, namely the free or saline ammonia and the albuminoid ammonia. The former is held to have its origin mainly in organic pollution, being virtually an early stage in the decomposition of such matter, while the latter, being derived from nitrogenous organic matter as a result of its breaking up by the addition of a solution of strongly alkaline potassium permanganate, is taken as the indication of pollution actually present as organic matter.

Although no better clue to the presence of organic matter can be well imagined than an estimation based upon the nitrogen resulting from its decomposition, still the difficulty exists in the fact that all hurtful organic matter is not necessarily nitrogenous. In the case of water pollution, this objection is largely theoretical, but it nevertheless suggests the fact that, as regards organic matter, much has yet to be learnt of its chemical constitution and detection. It is further obvious that no chemical process can decide whether any organic matter is living or dead, or whether, if living, it is injurious or not. Remembering how small the germs of disease are, it will be seen at once that even considerable numbers of them in a water cannot by themselves materially increase the organic ammonia; but as they are nearly always associated with an organic nutritive medium, the excessive presence of organic pollution, which analysis would necessarily indicate, at once suggests doubt and suspicion as to the purity of the water under examination.

Besides the combustion process, commonly known as Frankland's, and the ammonia determinations of Wanklyn, that of Kjeldahl, has been introduced for the determination of the total combined nitrogen, except nitrates, in natural waters. Although it cannot be claimed for them that they will estimate the absolute quantity of organic matter present, the Wanklyn and Kjeldahl processes constitute the two best methods of estimating its relative quantities in different waters, and, being readily performed by any medical officer of health, will be now described.

Determination of the Free Ammonia.—For this estimation it is necessary to have the following solutions:—

(1) *Nessler's Re-agent.*—This is a saturated solution of mercuric iodide in potassic iodide. It gives a yellowish tinge, with the faintest trace of ammonia, passing, if much ammonia is present, to the formation of a yellow-brown precipitate of the di-mercuric-ammonium iodide.

Nessler's solution is made by "taking 35 grammes of iodide of potash,

13 grammes of corrosive sublimate, and about 800 c.c. of water. These materials are then heated to boiling, and stirred up until the salts dissolve. That having been accomplished, a cold saturated solution of corrosive sublimate in water is cautiously added, until the red periodide of mercury, which is produced as each drop of the solution falls into the liquid, just begins to be permanent. In this manner we obtain the solution of the iodide of potassium saturated with mercury periodide, and it remains to render it sufficiently alkaline, and to render it sensitive. This is accomplished by adding 160 grammes of solid caustic potash, or 120 grammes of caustic soda, to the liquid, which is afterwards to be diluted with water, so that the whole volume of the solution may comprise one litre. In order to render the Nessler re-agent sensitive, it is mixed finally with a little more cold saturated solution of corrosive sublimate and allowed to settle."—(Wanklyn.)

(2) *A Standard Solution of Ammonium Chloride.*—Ammonium chloride, represented by the formula NH_4Cl, bears a ratio to ammonia, as represented by NH_3 of as 53·5 is to 17. Therefore, if 0·03147 gramme of ammonium chloride be dissolved in 1 litre of distilled water, that solution will equal 0·01 gramme of ammonia: and 1 c.c. of this solution will equal 0·01 mgm. of ammonia.

To perform the process, place 250 c.c. of the water sample in a retort, then attach the retort to the Liebig's condenser, and distil off about 130 c.c.; collect 1 c.c. more of the distillate, and test it with a few drops of Nessler, to see if any ammonia is still coming over; if so, the distillation must be continued longer. Carefully measure the amount of distillate; test a little with Nessler's solution in a test-tube; and, if the colour be not too dark, take 100 c.c. of the distillate and put it into a cylindrical glass vessel, placed upon a piece of white paper. Add to it 1·5 c.c. of Nessler. Pour into another similar cylinder as many c.c. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 c.c. with pure distilled water; drop in 1·5 c.c. of Nessler. If the colours correspond after three to five minutes, the process is finished, and the amount of ammonium chloride used is read off. If the colours are not the same, add a little more ammonium chloride so long as no haze shows itself; if it does, then a fresh glass must be taken, and another trial made. When the process is completed, read off the number of c.c. of ammonium chloride used, allow for the portion of distillate not used, multiply by 0·01 to give mgms. of NH_3; by 4 to bring to the litre; and by 0·1 to bring from mgms. to centigrammes; or shortly, multiply by 0·004: the result is centigrammes of free ammonia per litre, or parts per 100,000.

Example.—From 250 c.c. of water, 140 were distilled: 100 c.c. were taken for the experiment, and 2·3 c.c. of ammonium chloride solution were required to give the proper colour; then, $2{\cdot}3 \times \frac{140}{100} \times 0{\cdot}01 \times 0{\cdot}4 = 0{\cdot}01288$ per 100,000 of free ammonia.

Should the colour of the distillate, after the addition of Nessler's reagent, prove too dark, a smaller quantity may be used, and made up to 100 c.c. with distilled water. Wanklyn recommends distilling only 50 c.c., Nesslerising it, and then adding one-third of the result, on the ground that (as he says) three-quarters of the ammonia come off in the first 50 c.c. He also states that with smaller sized apparatus 100 c.c. of water give satisfactory results. The Society of Public Analysts recommend successive portions being distilled over, and Nesslerised until ammonia ceases to appear. Practically we have found that the whole of the ammonia

comes over in the first 130 c.c. or nearly so; but it is necessary to continue the distillation until ammonia has entirely ceased to come over.

When a Liebig's condenser cannot be obtained, a flask may be used instead of a retort, and the distillate conveyed to the receiver by a tube of glass (or block tin) passing through a vessel of cold water, which must be renewed from time to time. The tube may be bent in any convenient way, so as to expose it to the cooling water as much as possible. Every part of the apparatus must be scrupulously clean and well washed with distilled water previous to commencing the experiment. It is well to wash the retort, flask, and glass tubes with dilute sulphuric acid, and then rinse them out clean with distilled water. In distilling, the retort must not be thrust well into the flame; the distillation should be carried out so that about 50 c.c. come over in fifteen minutes. If the water is acid, the addition of a little pure or recently heated sodium carbonate may be made, but in ordinary circumstances it is not necessary, and is not advisable.

The typical yellow or brownish colour produced, when Nessler's solution is placed in the presence of minute quantities of ammonia, is due to the precipitation of the di-mercuric-ammonium iodide (NHg_2I), that is, ammonium iodide (NH_4I), from which the four atoms of the monad hydrogen have been displaced by two atoms of the dyad mercury; thus, $NH_3 + 2HgI_2 = NHg_2I + 3HI$.

The "free" or "saline ammonia" represents the ammonia combined with carbonic, nitric, or other acids, and also what may be derived from urea, or other easily decomposable substances, if they are present. The limit in pure waters is taken at 0·002 centigramme per litre; in bad waters it often reaches 100 times this and more; in usable waters it should not exceed 0·005.

After the distillation of the free ammonia, the residue of the water in the retort is used for determining the *albuminoid ammonia*, to be now described.

Determination of the Albuminoid Ammonia.—In addition to the Nessler's solution and the standard ammonium chloride solution used in the last process, the following is required:—

An alkaline Permanganate of Potash solution, made by dissolving 200 grammes of caustic potash and 8 grammes of potassium permanganate in 1100 c.c. of distilled water, and then rapidly boiling the solution down to 1 litre or 1000 c.c.

To make this determination, add to the residue left in the retort employed in the last process 25 c.c. of the alkaline permanganate solution, and 25 c.c. of ammonia-free distilled water. Proceed to distil over as before, and continue to do so until no more ammonia comes over; this it will generally cease to do after some 110 or 120 c.c. have been distilled. This ammonia is the so-called albuminoid, due to the breaking up of any organic matter present in the water under the influence of an oxidising agent in the presence of a caustic alkali. The determination of the ammonia in this case is conducted in precisely similar fashion as for the free ammonia.

Example.—Suppose 120 c.c. were distilled over; 100 c.c. were taken for the experiment; 4·5 c.c. of ammonium chloride solution were required to give the proper colour: then $4{\cdot}5 \times \frac{120}{100} \times 0{\cdot}01 \times 0{\cdot}4 = 0{\cdot}0216$ of albuminoid ammonia per 100,000.

In this process, before adding the alkaline permanganate solution to the residue in the retort, it is as well to boil it (the permanganate) for five minutes in order to get rid of any traces of ammonia which may be in it.

The object of this process is to get a measure of the nitrogenous organic

matter in water, by breaking it up and converting the nitrogen into ammonia by means of potassium permanganate in presence of an alkali; the ammonia can be distilled off and estimated as above. It is to be understood that this does not deal with *all* the nitrogenous matter, but the results are sufficiently uniform to be useful. As so calculated out, the albuminoid ammonia is approximately one-tenth of the nitrogenous matter in water.

In drinking waters of good quality, the albuminoid ammonia should not exceed 0·01 per 100,000. Much albuminoid ammonia, with a small amount of free ammonia, indicates usually vegetable contamination, particularly so if the chlorides, nitrites, and nitrates are low. Peaty waters commonly yield large quantities of albuminoid ammonia, which is evolved slowly and somewhat persistently; badly polluted waters, on the other hand, generally yield their high proportion of albuminoid ammonia promptly and sharply.

Determination of the Organic Nitrogen.—The application of Kjeldahl's nitrogen process affords a very convenient method for making this determination in natural waters, and is strongly recommended for the analysis of waters containing large quantities of nitrogenous material. If the specimen cannot be examined at once a little dilute sulphuric acid should be added, which will prevent the development of fermentation processes. The actual process is as follows:—

300 c.c. to 500 c.c. of the water, acidified with 5 or 10 c.c. of dilute sulphuric acid, are evaporated down to 100 c.c. and then transferred to a flask with a narrow neck. If more than traces of nitrates are present, 30 c.c. of cold saturated sulphurous acid are added, and after five minutes a few drops of chloride of iron are put in and the whole warmed for about twenty minutes on a water-bath. The temperature is then raised to the boiling-point and the contents of the flask evaporated to a syrupy consistence. 200 c.c. of pure sulphuric acid (containing 200 grammes of phosphorus pentoxide to the litre of acid), 0·05 gramme of oxide of copper, and 5 drops of a 4 per cent. solution of platinum chloride are then added. The flask is then placed in a slanting position, and the opening being closed with a small glass funnel, the contents are heated to boiling-point. At first aqueous vapour and SO_2 and SO_3 gases are given off, later chiefly SO_2 gas, which is known by the heavy fumes; the heat is now to be so arranged that the acid vapour will condense in the upper cool part of the flask and flow back again into the body of the flask. Care is to be taken that the flame does not come in direct contact with the flask, and the heating is continued until the fluid acquires a pure green colour. As a rule the oxidation process requires from one to two hours. The contents of the flask are allowed to cool, 80 c.c. of distilled water gradually added, a few pieces of zinc put in, and 100 c.c. of a solution of caustic soda (sp. gr. 1·36, and freed from ammonia by heating) are finally added. The flask is next connected to the special condenser and about half the fluid distilled off; the distillate is received in a measured quantity of deci-normal sulphuric acid, which is then titrated with deci-normal alkaline solution, using litmus as an indicator. The loss of acidity, as shown by a reduced volume of alkali required to neutralise the acid, represents the ammoniacal nitrogen which has passed over. Each c.c. of deci-normal sulphuric acid = 0·0014 gramme of nitrogen.

Determination of the Nitrites.—When organic matter putrefies or decomposes it becomes reduced to its absolute elements. Of these, nitrogen is the chief, and this combining with hydrogen forms first ammonia, hence the presence, more or less, of free or saline ammonia in a water when at all polluted with organic matter, such as raw sewage. In the course of time, or as it percolates through the soil, the ammonia in the

water acquires oxygen and gradually becomes partially oxidised to nitrous acid, HNO_2, or to nitric acid, HNO_3, which acids, by combining with bases like calcium, sodium, or potassium, form *nitrites* and *nitrates*. The oxidation of organic matter cannot go beyond the formation of nitric acid and nitrates, while the nitrous acid and nitrites mark an intermediate stage of imperfect oxidation.

The determination, therefore, of nitrites and nitrates in a water is important, as indicating either a pollution at some remote period with possibly dangerous matter, or more recently with a partially or completely oxidised sewage.

Waters fouled by vegetable matter yield, as a rule, little nitrite or nitrate, chiefly because not only does vegetable decomposition yield relatively little nitrogen, but also because the natural tendency of all plant life is to remove both nitrites and nitrates from a water.

For the direct determination of nitrites, in terms of nitrous acid (NO_2), two processes are available, namely, Griess's by means of meta-phenylenediamine and dilute sulphuric acid ; and Ilosvay's modification of Griess's test by means of sulphanilic acid and naphthylamine. Both are extremely sensitive, and require for their conduction one or more of the following solutions :—

(1) *Dilute Sulphuric Acid*, consisting of one volume of strong acid to two of distilled water.

(2) *A solution of Meta-phenylenediamine*, made by dissolving 5 grammes of meta-phenylenediamine in a litre of distilled water, rendered acid with sulphuric acid. This should be decolourised, if necessary, by filtering through animal charcoal.

(3) *A milli-normal Standard solution of Potassium Nitrite.*—Owing to the unstable nature of this salt, it is necessary to prepare it specially for making up this solution. By the following chemical equation,

$$AgNO_2 + KCl = AgCl + KNO_2,$$

it is seen that 154 parts of pure silver nitrite, in the presence of 74·5 parts of potassium chloride, are decomposed, with the formation of 143·5 parts of silver chloride and 85 parts of potassium nitrite, or 46 of nitrous acid, as represented by NO_2. Hence, if 1·54 grammes of pure silver nitrite be dissolved in hot water, decomposed with a slight excess of potassium chloride, allowed to cool, made up to a litre, we obtain a $\frac{N}{100}$ solution of potassic nitrite equalling 0·46 gramme of nitrous acid as NO_2. If each 100 c.c. of this solution, after standing and subsidence of the silver chloride, be again diluted up to a litre with distilled water, we get a $\frac{N}{1000}$ solution of KNO_2, equalling 0·046 gramme of NO_2, and each c.c. of which equals 0·046 of a milligramme of NO_2.

(4) *A solution of Sulphanilic Acid*, made by dissolving 0·5 gramme in 150 c.c. of diluted acetic acid (sp. gr. 1·04).

(5) *A solution of Naphthylamine*, made by dissolving 0·1 gramme in 20 c.c. of distilled water, then filtering and mixing the filtrate with 180 c.c. of dilute acetic acid.

Griess's test is thus performed. One c.c. of the dilute sulphuric acid and 1 c.c. of the meta-phenylenediamine solution are added to 100 c.c. of the water to be examined, and placed in a Nessler glass ; if an orange colour is immediately produced, the tint will prove too deep for comparison, and another trial must be made with 50 c.c. of the water diluted up to 100 c.c. of distilled water, when probably only a faint colour will be perceived. The

object of this preliminary trial is to find out the amount of the water which can be used in the experiment; the proper amount to use is that which gives only a faint trace of colour on the addition of the re-agents. Having decided the amount which can be used, it must, if less than 100 c.c., be diluted up to this amount with distilled water and then placed in a Nessler glass. Trial glasses containing different amounts of the standard nitrite solution diluted up to 100 c.c. with distilled water are then made. One c.c. of the dilute sulphuric acid and 1 c.c. of the meta-phenylenediamine are next added to the Nessler glass containing the water to be examined and to each of the trial glasses as quickly as possible, so that the colours in the glasses may develop from exactly the same time. The glasses are compared at the end of ten to fifteen minutes and the amount of standard solution determined, which gives the same colour as the nitrite in the water under examination. If the tints are not exactly matched at the first trial, a second attempt must be made, all the glasses being again filled at exactly the same time. The standard potassium nitrite, being of the strength of 1 c.c. = 0·046 milligramme of NO_2, the number of c.c. used gives the milligrammes of nitrous acid present in the sample of water.

Example.—A sample of water containing a good deal of nitrous acid is taken, and 25 c.c., made up to 100 c.c. with pure distilled water, and put in a Nessler glass. One c.c. of the sulphuric acid and 1 c.c. of the solution of meta-phenylenediamine added: a distinct orange colour is obtained. Into another Nessler glass 2 c.c. of the standard potassium nitrite are put, made up to 100 c.c. with distilled water, and the same shade of tint obtained with the solution as above.

Then, $2 \times 0·046 \times 4 = 0·368$ mgms. NO_2 in 100 c.c. of water or parts per 100,000. Multiplying this by $\frac{N}{NO_2} = \frac{14}{46} = 0·112$ gives the equivalent in terms of nitrogen.

The above is a very accurate method of determining nitrites, but some care is required, for both the water and the colouring solution must be either colourless or decolourised. The chief objections to Griess's test are that the colour reaction only develops after some five minutes, and the solutions are liable to change.

It may be well to mention here that the method of stating the results varies, as in the case of nitric acid, some reckoning as HNO_2, some as N_2O_3, and others as NO_2. The last is the best, as it corresponds to Cl. In the same way NO_3 is to be preferred for the nitric acid, SO_4 for the sulphuric acid, and PO_3 for the phosphoric acid.

Ilosvay's test is performed by placing 100 c.c. of the water sample in a colour comparison or Nessler glass, and then, by means of a pipette or burette, adding 2 c.c. each of the solutions of sulphanilic acid and naphthylamine. If nitrites are present, a pink colour is produced. Into another clean glass 1 c.c. of the standard nitrite solution is placed, made up with nitrite-free water to 100 c.c., and treated with the re-agents as above. At the end of five minutes the colours of the two solutions are compared, and equalised by diluting the darker.

Example.—Suppose the 100 c.c. of water sample is darker than the distilled water, containing 1 c.c. of the standard nitrite solution. It is necessary to dilute the water sample down to the tint given by the other: 60 c.c. of the 100 c.c. are taken and made up to 100 with distilled water; on comparison, suppose the colour to be still too deep: 70 c.c. of this diluted water is then taken and compared with the other. Presuming that the colours or tints now coincide, we get $100 \times \frac{60}{100} \times \frac{70}{100} = 42$ of the original 100 c.c. equal to 1 c.c. of the standard potassium nitrite solution, which again equals 0·046 mgm. of NO_2: therefore $\frac{100 \times 0·046}{42} = x = 0·109$ mgm. NO_2 in 100 c.c., or 0·109 part per 100,000.

Had the glass containing the 1 c.c. of standard solution been the darker,

that could have been diluted down in a similar way, and the various fractions calculated as parts of 1 c.c. or equivalents of 1 c.c. in terms of NO_2.

The reactions in this process consist in the conversion of the sulphanilic acid into diazo-benzene sulphonic anhydride, by the nitrites present: this compound is in turn then converted by the naphthylamine into azo-alpha-amido-naphthalene-parazobenzene sulphonic acid. It is this last-named compound which gives the pink colour to the liquid. Thus,

$$\underset{\text{Sulphanilic acid.}}{C_6H_7NSO_3} + \underset{\text{Nitrous acid.}}{HNO_2} = \underset{\text{Diazo-benzene sulphonic acid.}}{C_6H_4N_2SO_3} + 2H_2O$$

$$\underset{\text{Diazo-benzene sulphonic acid.}}{C_6H_4N_2SO_3} + \underset{\text{Naphthylamine.}}{C_{10}H_7NH_3Cl} = \underset{\text{Azo-alpha-amido-naphthalene-parazobenzene sulphonic acid.}}{C_{10}H_6(NH_2)NNC_6H_4HSO_3} + HCl.$$

It may be accepted as a good rule that no water which shows the presence of nitrites is fitted for domestic use.

Determination of the Nitrates.—For this estimation we have two convenient processes, either of which can be readily performed; they are (1) the phenol-sulphuric acid method, and (2) the aluminium process.

Phenol-sulphuric Acid Method.—This method is simple in its application, and yields good results; for it the following solutions are required:—

(1) *Phenol-sulphuric Acid*, made by adding 6 grammes of pure phenol and 3 c.c. of distilled water to 37 c.c. of strong sulphuric acid free from nitrates.

(2) *Standard solution of Potassium Nitrate*, made by dissolving 0·072 gramme of recently fused nitrate of potassium in water, and the solution subsequently made up to a litre. One c.c. of this solution will contain 0·01 milligramme of nitrogen.

The process is thus performed: 10 c.c. of the water under examination and 10 c.c. of the standard potassium nitrate solution are evaporated separately just to dryness in two porcelain or platinum dishes. To each of the residues, 1 c.c. of the phenol-sulphuric acid is added and thoroughly mixed by means of a glass rod. If the water under examination contains a large amount of nitrates, the liquid will quickly turn red; if it contain but a small quantity, this colour will not appear for about ten minutes. After the dishes have stood for from ten to fifteen minutes, their contents are washed out successively with 25 c.c. of distilled water into two clean Nessler glasses, about 20 c.c. of liquor ammonia added (sp. gr. 0·96) and both made up to 100 c.c. with more distilled water.

Any nitrate present in the solutions converts the phenol-sulphuric acid into picric acid, which, by the action of the ammonium, forms ammonium picrate; this gives a yellow colour to the solution, the intensity of which is proportional to the amount present.

The colours of the two solutions are now compared, and the darker one diluted until the tints are adjusted, the calculation being made as explained in the description of Ilosvay's test for nitrites. The comparative volumes of the liquids furnish the necessary data for determining the amount of nitrate.

In the case of very good waters, it is better to evaporate down 20, 50, or more c.c. of the sample and only 5 c.c. of the standard nitrate of potassium; if the water under examination be very rich in nitrates, 10 c.c. of the sample should be pipetted into a 100 c.c. measuring flask, and made up to the mark with distilled water, then 10 c.c. of this well-mixed and diluted liquid (= 1 c.c. of original water) withdrawn, evaporated, and treated as above.

Aluminium Process.—If to a strongly alkaline water some aluminium foil be added decomposition of the water ensues with the evolution of hydrogen. If nitrites or nitrates be present in the water, these salts are reduced by the hydrogen with the result that, on being boiled, their nitrogen is given off as ammonia.

The re-agents required for the determination of the nitrates are (1) some thin aluminium foil, and (2) a solution of sodium hydrate. This is best made by dissolving 100 grammes of solid sodium hydrate in 1 litre of distilled water. When cold, introduce a strip of aluminium foil, previously heated to just short of redness, wrapped round a glass rod. When the aluminium is dissolved, boil the solution briskly in a porcelain basin until about one-third of its volume has evaporated ; allow it to cool and make it up to its original volume with ammonia-free distilled water. The solution should be tested to prove the absence of nitrates.

100 c.c.of the water sample with 100 c.c. of the sodium hydrate solution and a strip of the aluminium foil are placed in a retort, corked, and left for six or more hours. At the termination of this time, heat must be applied, after connecting the retort with a condenser, and the ammonia present in the flask contents distilled over in precisely the same way as described for estimating the free and albuminoid ammonias. The ammonia which will come over in the distillate will consist partly of any free ammonia which may be present in the sample, partly of ammonia due to reduction of nitrites, if any be present, and partly of ammonia due to reduction of nitrates, if they be present. After elimination of the two former, the remaining ammonia will represent nitrates, and from it the quantity of nitric acid as nitrates can be readily estimated.

The principle of this process consists in the deoxidation of nitric acid or nitrates, and consequent formation of ammonia by evolution of hydrogen. Thus,

$$4Al + 4NaHO + 4H_2O = 2Al_2Na_2O_4 + 6H_2$$
$$12H_2 + 3KNO_3 = 3KHO + 6H_2O + 3NH_3.$$

Example.—Presume that the whole of the ammonia has come over in 120 c.c. Ten c.c. of this distillate are taken for experiment, and diluted to 100 c.c. ; on Nesslerising, 4 c.c. of the ammonium chloride solution are found to give the required colour. Then $4 \times \frac{120}{10} \times 0{\cdot}01 = 0{\cdot}48$ mgm. of ammonia in 100 c.c. of water or parts per 100,000. This 0·48 part of ammonia in 100,000 is the total ammonia yielded by the 100 c.c. of water sample, and includes not only free ammonia (if any), but also ammonia due to nitrites (if any) and nitrates.

Suppose this particular water sample to have already yielded 0·005 of free ammonia and 0·52 of nitrites as NO_2, both in parts per 100,000. The 0·52 of NO_2 is convertible into NH_3 in the ratio of as 46 is to 17, or $\frac{17 \times 0{\cdot}52}{46} = 0{\cdot}192$ of NH_3, and this added to the 0·005 of free $NH_3 = 0{\cdot}197$ of ammonia per 100,000 to be deducted from the total ammonia before we get the NH_3 due solely to the reduction of any nitrates present. This means $0{\cdot}48 - 0{\cdot}197 = 0{\cdot}283$ per 100,000 of NH_3 representing nitrates as NO_3. Converting this NH_3 into terms of NO_3, we get $\frac{62 \times 0{\cdot}283}{17} = 1{\cdot}032$ mgms. of NO_3 in 100 c.c. of the sample or parts per 100,000.

Expressed as nitrogen, this equals 0·233 part per 100,000.

Speaking generally, no water used for drinking purposes should contain more than 0·35 part per 100,000 of nitrogen in the form of nitrates ; this equals about 1 grain per gallon of N_2O_5 or 1·5 parts of NO_3 per 100,000.

The Committee of the British Association (1899) appointed to establish a uniform system of recording results suggest that all nitrogen compounds be expressed as parts of nitrogen per 100,000, including the ammonia expelled on boiling with alkaline permanganate, which should be termed albuminoid nitrogen.

Determination of Oxygen-consuming Power.—Although, by itself, of little value as a measure of the organic impurity of a water sample, this determination of its affinity for oxygen, when taken in conjunction with other analytical facts, is often a material aid in forming an opinion as to the quality of any particular water. Much of the organic matter present in water is capable of oxidation, but since the ease of oxidation bears no constant ratio to the nature of the organic matter, its estimation affords no very reliable index to the real pollution present. In all the efforts to judge the oxidisable organic matter, advantage is taken of the fact that, in the presence of most organic substances, permanganate of potassium freely parts with its oxygen until all the permanganate has been reduced to hydrated manganese dioxide; thus, $2KMnO_4 = K_2MnO_4 + MnO_2 + O_2$. Unfortunately, different substances reduce different proportions of permanganate, and slight variations in temperature and acidity or alkalinity materially influence the readiness with which the permanganate parts with its oxygen.

To determine the oxidisable organic matter, use is best made of what is known as Tidy's process. This process is based upon the chemical fact that, in the presence of an acid and heat, the following decomposition of permanganate takes place:—$4KMnO_4 + 6H_2SO_4 = 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2$, or in other words, 632 parts of potassium permanganate yield in the presence of sulphuric acid 160 parts of oxygen.

For Tidy's process, the following solutions are necessary:—

1. *Standard Potassium Permanganate Solution.*—Since 632 parts of the salt with an acid yield 160 parts of oxygen, then 0·316 gramme of potassium permanganate, if dissolved in a litre of water, will be equivalent to 0·08 gramme of oxygen. This constitutes the standard solution; 1 c.c. of it used with acid yields 0·08 mgm. of oxygen.
2. *Potassium Iodide Solution.*—A 10 per cent. solution in distilled water.
3. *Sodium Thiosulphate Solution.*—One gramme dissolved in a litre of distilled water.
4. *Starch Solution.*—One gramme of starch mixed with half a litre of distilled water, boiled for five minutes, and filtered.
5. *Dilute Sulphuric Acid*, consisting of one volume of strong acid to three of distilled water.

In performing this process, Tidy recommended two determinations to be made, namely, one of the oxygen absorbed after fifteen minutes' exposure at a temperature of 80° F., and one after four hours' exposure at the same heat. He considered that during the first quarter of an hour, the more or less putrescent easily oxidised animal organic matters were oxidised, while the oxidation of the vegetable organic material did not take place till after four hours or so. Practically, as much information as can be gained is obtained at the end of fifteen minutes; therefore, except in special cases, the second observation after four hours is hardly necessary. If required, it is performed exactly in the same manner as the shorter exposure.

Into a stoppered bottle, capable of holding from 300 to 400 c.c., place 250 c.c. of the water sample, run in 10 c.c. of the sulphuric acid, and heat in a water-bath to 80° F. (26°·7 C.); when the required temperature is reached, add 10 c.c. of the permanganate solution. A pink colour will result. Maintain the bottle contents at 80° F., carefully noting whether the pink tint is discharged; if the tint disappear add more permanganate. At the end of fifteen minutes, add to the water three drops of the iodide of potassium solution. Owing to there being a certain amount of oxygen available from the permanganate, as previously explained, this will liberate

iodine from the iodide, with the result that the pink-coloured bottle contents will now become yellow; thus, $5O_2+20KI+10H_2O=20KHO+10I_2$.

The quantity of iodine set free will, of course, be dependent on the amount of potassium permanganate remaining unreduced in the water. If the iodine set free is absolutely dependent upon the amount of permanganate left unreduced by the organic matter in the water, it is obvious that any estimation of the iodine liberated will be a measure of the unused oxygen, and this, deducted from what was rendered available by the orginal quantity of permanganate added, will give a measure of the oxidisable organic mater in the 250 c.c. of water.

We proceed to make these estimations in the following manner. To the iodine-tinted water, the thiosulphate solution is gradually added with the object of reducing it; thus, $I_2+2Na_2S_2O_3=2NaI+Na_2S_4O_6$. In order to know exactly when all the free iodine has been removed from the water, an indicator in the form of 1 c.c. of the starch solution is added; this, so long as any free iodine is present, will give a blue tint. Therefore, continuing the addition of the thiosulphate, we stop the moment all the blue colour has gone, and read off the actual amount of thiosulphate used.

Unfortunately, thiosulphate of soda is a very unstable salt, and its particular value as a reducing agent needs to be judged, at the time of each experiment, by means of a control observation of its powers upon an identical quantity of permanganate in distilled water, as was used for the unknown sample. Accordingly, into a similar bottle, 250 c.c. of distilled water are placed, heated to 80° F., 10 c.c. of the sulphuric acid, and exactly the same amount of permanganate as was used for the water sample added, and the whole kept at 80° F. for fifteen minutes. In this bottle, owing to there being no organic matter, practically the whole of the oxygen liberated from the permanganate under the circumstances will be unconsumed, and consequently on the addition of three drops of potassium iodide, more iodine will be liberated, and more of the thiosulphate will be required to reduce it. The iodide, the starch, and the thiosulphate are added precisely as in the other experiment.

So soon as all the iodine has been removed, as shown by the disappearance of the blue colour, the amount of thiosulphate used is read off; its volume will represent, for the time being, the actual reducing value of the thiosulphate for the precise amount of permanganate used or added in the experiment. And the difference between the amount of thiosulphate solution needed to reduce the x amount of potassium permanganate in the pure distilled water, and that required for the same amount which has been more or less decomposed or reduced by oxidisable organic matter in the water sample, will represent the quantity of oxygen consumed by such oxidisable matter.

Example.—Say 10 c.c. of $KMnO_4$ in the distilled water have used up 40 c.c. of the thiosulphate solution; therefore, 40 c.c. of the thiosulphate may be considered as equivalent to 10 c.c. of $KMnO_4$ or 0·8 mgm. of oxygen.

Another 10 c.c. of $KMnO_4$, in the unknown sample, have used up, say, 32 c.c. of thiosulphate solution: therefore, an amount of oxygen equivalent to the difference between 40 and 32 c.c. of thiosulphate solution has been taken up by the organic matter. But if 40 c.c. of thiosulphate equal 0·8 mgm. of oxygen, then 8 c.c., or the difference between 40 and 32, equal 0·16 mgm. of oxygen. This means that 0·16 mgm. of oxygen is taken up by 250 c.c. of the water sample, or parts per 250,000; this multiplied by 0·4 equals 0·064 part of oxygen consumed by the oxidisable organic matter per 100,000.

In performing this process, the permanganate added must be sufficient to create a pink colour, which remains distinctly permanent at the end of the heating. If the four hours' test be applied, it may be necessary to make repeated additions of the permanganate solution. The *total* quantity

actually used must be carefully noted, and the same amount, of course, employed in the distilled water experiment.

In endeavouring to interpret the results of this oxygen-consuming process, it must be borne in mind that besides organic matter, iron salts, nitrites, and sulphuretted hydrogen will reduce permanganate of potassium; and these latter, if present, must be duly allowed for. It is difficult to distinguish between the oxygen consumed by the nitrogenous and the non-nitrogenous matter. Roughly speaking, the four hours' experiment gives information as to the total amount of oxidisable organic matter, while the fifteen minutes' reaction is valuable as indicating the proportion of putrescent or readily oxidisable, and presumably dangerous, material. Peaty waters consume large quantities of oxygen; hence, as in all other attempts to measure the organic mater in a water sample, the result of the oxygen process must be considered in conjunction with the other analytical data and the source of the water.

In a general way, it may be said that waters of great organic purity will not consume more than 0·05 of oxygen per 100,000 in fifteen minutes at 80° F., and that, when the oxygen consumed exceeds 0·1 per 100,000, the sample may be considered of doubtful purity. If, after four hours' exposure, more than 0·3 part of oxygen is consumed per 100,000 of water, the sample must be regarded with suspicion.

Determination of Dissolved Oxygen.—This estimation in connection with water analysis has hitherto been much neglected. For hygienic purposes, a method of estimating dissolved oxygen must be simple, speedy, and accurate, and must not require large quantities of water. A further condition is that the water must not be subjected to a diminished oxygen pressure, *i.e.*, must not be operated upon in an atmosphere of inert gas, otherwise there might be, according to the experiments of Roscoe and Lunt, a rapid loss by diffusion.

Several methods for determining the dissolved oxygen in water have been proposed, the more notable being those of Winkler, Dibdin, Thresh, and Mohr. The chief objection to them all has been the necessity of special apparatus. As being perhaps the most simple and readily applied, we here describe Winkler's process.

The following solutions are required for the process:—

(1) *Manganous Chloride solution*, made by dissolving 80 grammes of $MnCl_2 4H_2O$ in 100 c.c. of distilled water. The solution must be free from iron.

(2) *Potassium Iodide and Caustic Soda solution.*—Dissolve 10 grammes of iodide of potassium in 100 c.c. of a 33 per cent. solution of pure caustic soda. This solution, when diluted with water and acidified with sulphuric acid, ought not to give any colour with a solution of starch.

(3) *Centinormal solution of Iodine*, made by dissolving 1·27 grammes of pure dry iodine and 2 grammes of iodide of potassium in 20 c.c. of distilled water, and then making up to 1 litre with distilled water.

(4) *Centinormal solution of Thiosulphate of Soda*, made by dissolving 2·48 grammes of pure dried $Na_2S_2O_3.5H_2O$ in a litre of distilled water. This solution must be kept in the dark and in a cool place; as its value tends to alter, it should be titrated before use with the above iodine solution, diluted with water and in the presence of some starch solution; 10 c.c. of the iodine solution should require 10 c.c. of the thiosulphate solution for decolourisation.

(5) *Starch solution*, as prepared for the estimation of the oxygen-consuming power of a water.

The process is as follows: Take a glass bottle provided with a well-fitting glass stopper, and having approximately a capacity of 300 c.c. Determine

accurately the capacity of the bottle. Wash out the bottle thoroughly with some of the water to be examined, and then fill it to overflowing. Introduce, by means of a graduated pipette, having a long narrow point, 1 c.c. of the iodide and soda solution, and also 1 c.c. of the manganous chloride solution. Do this carefully and gradually, so that the point is close to the bottom of the bottle. Put in the stopper tightly, and see that no air-bubbles remain. Mix the contents by swinging the bottle lightly round; allow the precipitate which forms to settle down; if it does not settle readily, the bottle should be allowed to stand for an hour or so, but taking care that no air gains access to the bottle contents. When the precipitate has settled down and the fluid in the upper part of the bottle is clear, introduce carefully down the side, by means of a pipette, from 3 to 5 c.c. of fuming hydrochloric acid (sp. gr. 1·16 to 1·18), so as to let it fall on to the precipitate; replace stopper, and swing the bottle gently round until the precipitate dissolves. The iodine-tinted fluid in the bottle is now washed out into a clean beaker with distilled water, and then titrated in the presence of starch with the thiosulphate solution, 1 c.c. of which equals 0·0000798 grammes or 0·055825 c.c. of oxygen. The iodine liberated corresponds to the oxygen present in the water, therefore the cubic centimetres of thiosulphate used multiplied by 0·055825 give the cubic centimetres of oxygen present in the original volume of water placed in the bottle, less two or whatever volumes of the iodide and manganous solutions have been added. The various chemical reactions which take place in the process may be expressed by the following equations :—

$$2MnCl_2+4NaOH=4NaCl+2Mn(OH)_2.$$
$$2Mn(OH)_2+O+H_2O=2Mn(OH)_3.$$
$$2Mn(OH)_3+6HCl=2MnCl_3+6H_2O.$$
$$2MnCl_3+2KI=2MnCl_2+2KCl+I_2.$$

Example.—Say the capacity of the bottle was found to be 280 c.c. After the necessary manipulations had been made, assume that 32·9 c.c. of the thiosulphate solution were used to decolourise the iodised water. This will represent 1·8366 c.c. of oxygen in 278 c.c. of water, or 6·6066 c.c. in a litre. A correction for temperature and pressure is not necessary.

It must be borne in mind that this process needs to be done rapidly and at once; it is also interfered with by the presence of much organic matter, which absorbs the liberated iodine, and by the presence of nitrites, which, when acidified, set free iodine. Such interference can be prevented to a great extent by working very rapidly and using as little starch as possible. The amount of dissolved oxygen in a water is influenced largely by temperature, being less in summer and greater in winter. Roscoe and Lunt give the following figures as representing the cubic centimetres of oxygen in a saturated water at different temperatures, namely, at 5° C. 8·68, at 10° C. 7·77, at 15° C. 6·96, and at 20° C. 6·28. Ordinary tap-water in this country contains on an average 7 c.c. of dissolved oxygen per litre; this is about 1 part by weight per 100,000.

Determination of Iron.—This quantitative determination is required occasionally, and can be performed conveniently by the following process, for which these solutions are needed :—

A standard solution of Ferric Sulphate.—Dissolve 0·0496 gramme of ferrous sulphate in distilled water acidified with sulphuric acid, and add potassium permanganate solution until a faint pink colour is produced. The solution is then diluted to a litre. One c.c. of this solution contains 0·01 milligramme of iron.

Dilute Nitric Acid.—Dilute 30 c.c. of pure concentrated nitric acid with distilled water to about 100 c.c.

A solution of Potassium Sulphocyanate.—Fifteen grammes dissolved in 100 c.c. of water.

To make a quantitative estimation of iron, acidify 50 c.c. of the water sample with pure hydrochloric acid, and add just sufficient dilute potassium permanganate solution to convert any iron which may be present to the ferric state. Next evaporate this pink-tinted solution nearly to dryness, in order to drive off excess of acid, then dilute to its original volume of 50 c.c. with distilled water. Into each of two Nessler glasses place 5 c.c. of the dilute acid and 5 c.c. of the potassium sulphocyanate solution. To one of these a measured volume of the treated water is added and both glasses filled up to 50 c.c. with distilled water. If any iron be present in the treated water, a blood-red colour will be produced in the glass to which a measured volume was added. Into the other glass some of the standard iron solution is added until the colour agrees. The precise amount of the treated water to be added to the first glass will depend upon the quantity of iron present; but as a rule not more should be used than will require 2 or 3 c.c. of the standard iron solution to match it, otherwise the colour produced will be too deep for accurate comparison. The subsequent calculation is obviously simple, as each cubic centimetre of iron solution represents 0·01 mgm. of iron. The result can be expressed either as parts per 100,000 or as grains per gallon.

Determination of Lead.—As drinking waters very rarely contain copper, the amount of lead present can be conveniently determined by the following method.

A standard solution of Lead Acetate is prepared by dissolving 0·183 gramme of the crystallised salt in a litre of distilled water. One c.c. of this solution contains 0·1 milligramme of metallic lead.

100 c.c. of the water to be examined are placed in a Nessler glass and acidified by the addition of a few drops of acetic acid; to this is now added 0·5 c.c. of a saturated solution of ammonium sulphide. If any lead be present a brownish black coloration will be produced. Into another similar vessel 100 c.c. of distilled water are placed, together with the same quantities of acetic acid and ammonium sulphide, and sufficient of the standard lead solution added to match the tint in the other glass. From the amount of lead solution used, the quantity of lead in the water under examination is readily calculated. The result should be expressed both in parts per 100,000 and in grains per gallon.

Many waters, especially those that are soft and peaty, and therefore liable to act on lead, possess sufficient coloration to equal 0·5 or even 1 c.c. of the lead solution; if this is the case, a proportionate reduction should be made before calculating out the amount of lead present. By this method 0·05 per 100,000 or $\frac{1}{30}$th grain per gallon may be easily detected.

Copper, Arsenic, and Zinc.—The mere presence of these metals in appreciable quantity is enough to condemn a water, therefore it will seldom be necessary to determine their amount quantitatively.

Determination of Carbonic Acid.—As carbon dioxide is always being absorbed from the atmospheric air, and especially from the ground air, water without carbonic acid does not occur. Carbonic acid may exist in water in three states, namely, as carbonates, bicarbonates, and free acid. The usual German expressions are "combined or fixed" for that existing as simple carbonates, "half-bound" for that necessary to convert the carbonates into bicarbonates, and "free" for that remaining in excess. As practically all the so-called free and half-bound carbon dioxide is expelled from a water on boiling, the sum of these two constitutes what may be

called the volatile carbonic acid. The combination of carbon dioxide is effected chiefly in the form of acid salts of the alkaline earths, especially acid calcium carbonate. If an aqueous solution of this salt is boiled, or even allowed to stand exposed to the air, it is split up into carbonic acid and neutral calcium carbonate. This neutral calcium carbonate is almost insoluble in water, and is stable; the so-called acid calcium carbonate (calcium bicarbonate) has a distinctly alkaline reaction.

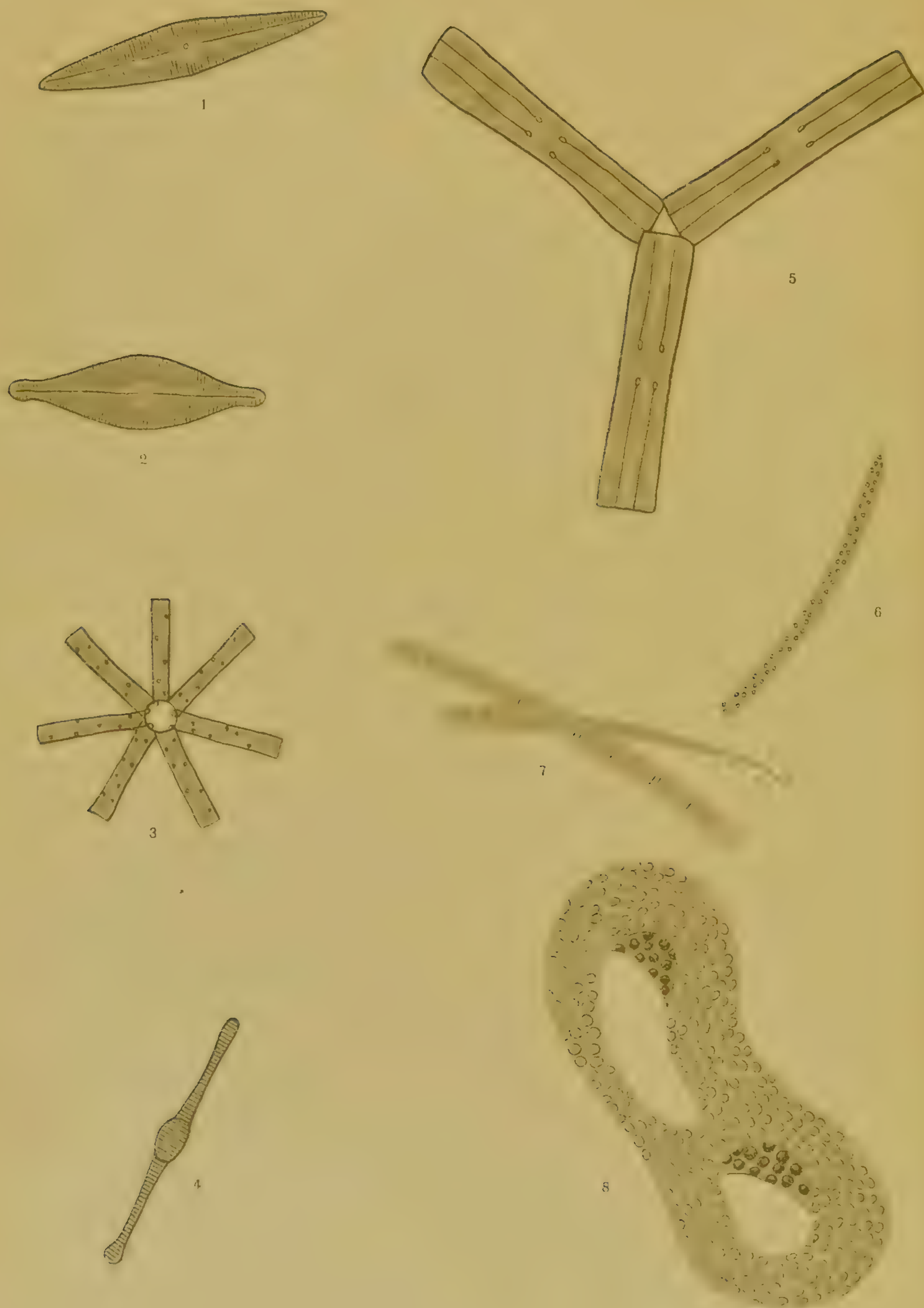
In order to determine the amount of carbon dioxide which exists both free and as bicarbonate, Pettenkofer's method will be found convenient. It is performed as follows: Place 200 c.c. of the water in a dry flask and add 10 c.c. of a neutral saturated solution of calcium chloride, 5 c.c. of a saturated solution of ammonium chloride, and 35 c.c. of baryta water, standardised, immediately before testing, with oxalic acid. The chloride of calcium will decompose any alkaline carbonate or any other alkaline salt whose acid would be precipitated by lime or baryta, the ammonium chloride will prevent the precipitation of any magnesia present. The flask is then tightly closed with an india-rubber stopper, well shaken, and allowed to stand for twelve hours. Two portions of 50 c.c. are then decanted off, taking care not to disturb the precipitate. The free uncombined baryta is then estimated in both portions by means of oxalic acid (1 c.c. = 1 mgm. CO_2), using phenol-phthalein as an indicator. The number of c.c. of standard oxalic acid required for 50 c.c. is then multiplied by 5 (there were 250 c.c. of water in the flask) and this amount deducted from the number of c.c. of standard oxalic acid required to neutralise 35 c.c. of the original baryta water; the difference gives the amount of baryta precipitated by the carbon dioxide present in the free state and as bicarbonate.

The presence of free carbonic acid is an almost constant characteristic of ground water. The amount varies, but may be as high as 13 parts per 100,000; it appears to be in inverse ratio to the dissolved oxygen. The source of the free carbon dioxide in ground water is apparently the ground air, increasing with the depth and decreasing with the porosity of the soil. When ground water is exposed to the air it may rapidly lose its free carbon dioxide, and even become alkaline to phenol-phthalein. Such waters generally contain magnesium carbonate, and betray their exposure to the air by becoming saturated with dissolved oxygen.

The estimation of free and combined carbon dioxide is further of interest in regard to the reaction of a water, and also in connection with its action on lead. Waters which contain both free and combined carbon dioxide are often distinctly *amphioteric*; that is, they turn red litmus paper blue, and blue paper red. These reactions are probably explicable as the result of a competition for the base between the free carbon dioxide and the red litmus, which is itself a weak acid, having blue salts. If some of the red paper is placed in a solution containing carbonates and free carbon dioxide, it seizes a portion of the base until equilibrium is established. If the blue paper be placed in the solution, the free carbon dioxide attacks it for part of the base, and liberates red litmus until the same condition of equilibrium is reached. Practically, testing the reaction of a water with litmus paper is much better replaced by an estimation of the free and combined carbon dioxide.

In its connection with the action of water upon lead, the relative amounts of free and combined carbon dioxide are often important factors. Frequently, waters which act upon lead contain more free than combined carbonic acid, and yet are distinctly alkaline to red litmus paper. In testing the action on lead, it is of importance to conduct the experiments in closed vessels,

PLATE I.

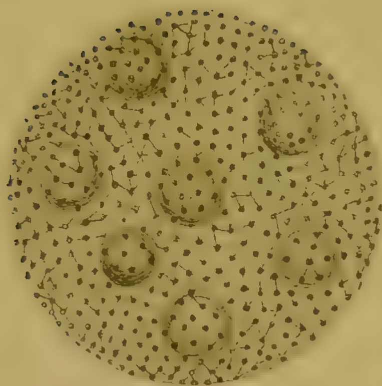


1 Navicula gracilis. × 500
2 Navicula rhyncocephala × 500
3 Asterionella. × 500
4 Tabellaria fenestrata × 500
5 Tabellaria flocculosa × 500
6 Beggiatoa. × 500
7 Crenothrix × 500
8 Clathrocystis. × 500

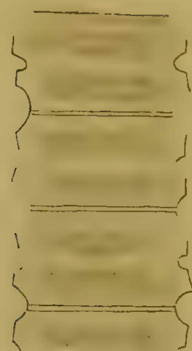
PLATE II.

1 Cœlosphærium. × 500
2 Nostoc. × 500
3 Anabœna. × 500
4 Asphanizomenon. × 500
5 Rivularia. × 500
6 Dictyosphœrium. × 500
7 Cœlastrum. × 500

PLATE III.



1



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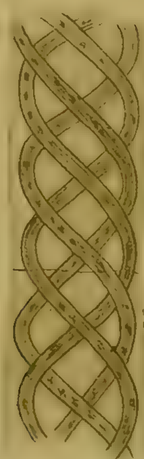

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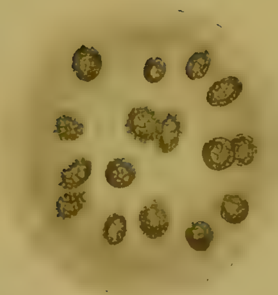
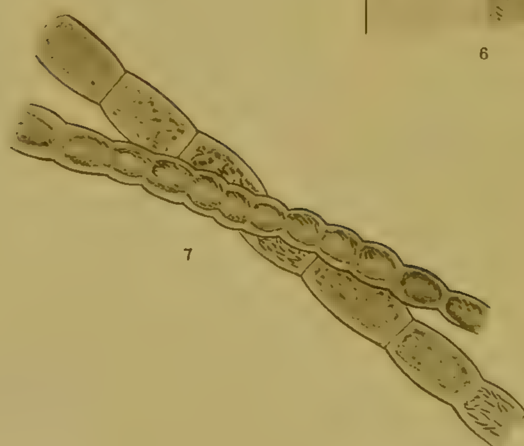


2



7

3

1 Volvox. × 100
2 Eudorina. × 250
3 Pandorina. × 250
4 Desmidium. × 500
5 Spirogyra. × 120
6 Spirogyra, containing spores. × 120
7 Conferva. × 120

as well as in open beakers, to prevent the loss of carbon dioxide, as the results will be sometimes found positive in the former and negative in the latter.

Microscopic Examination of Suspended and Sedimentary Matter.—The suspended matters may be either mineral or dead animal or vegetable matters, or living creatures (plants and animals).

To determine the nature of the suspended matters pour some of the water into a long glass as already described, and observe its appearance. Suspended sand or clay gives a yellow or yellow-white turbidity; vegetable humus and peat give a darkish, sewage gives a light brown colour; but the colour or turbidity alone is a very insufficient test. Then boil the water, and pour it back into the long glass. Sand, chalk, and heavy particles of the kind will be deposited; finely suspended sewage and vegetable matter is little affected, unless it be a chalk-water, when the deposit of calcium carbonate may carry down the suspended matter.

If the matter is entirely suspended, a drop of the water must be taken at once; but when it can be obtained, a little of the sediment is more satisfactory. To get a sediment, the water should be placed in a conical glass (the space of which ought to be *rounded*, not *pointed*, at the bottom), carefully covered and allowed to stand for a few hours; the upper part of the water is then poured away or siphoned off. The best kind of pipette for taking up the sediment for transfer to the glass slide is a plain straight tube, without bulb and without any narrowing to a point at either end; the diameter may be from $\frac{1}{16}$th to $\frac{1}{8}$th of an inch, or say from 1·5 to 3 millimetres.

The nature of the suspended matter varies greatly, embracing such diverse objects as mineral grit, sand, flint, chalk and mica particles, woody fibre, fragments of leaves, starch cells, macerated paper, amorphous vegetable *débris*, hairs, feathers, down, cotton, wool or silk fibres, and scales or wings from insects. The foregoing are all inanimate, but in addition there is often much animate vegetable material, such as fungi, either as spores or mycelia, and numerous forms of algæ, as well as living animal forms, such as protozoa, rhizopoda, infusoria, crustacea, insects, worms and their ova. The presence of the spores and mycelia of the higher fungi indicates impurity, probably derived from sewage, since the latter usually contains phosphates, without which these forms cannot live. Algæ, diatoms, desmids and other organisms are common in open wells, lakes, ponds and streams; they are not an infrequent cause of the peculiar odour developed in such waters. Whipple * classifies the various odours, which appear in potable waters, as aromatic grassy, and fishy, and for convenience states their causes to be as follows. The aromatic odour is generally due to *cryptomonas* or *mallomonas* among the protozoa, or to *asterionella*, *cyclotella*, *diatoma*, *meridion*, or *tabellaria* among the diatomaceæ. The grassy smell is due usually to *anabæna*, *cœlospherium*, *clathrocystis*, *aphanizomenon*, or *rivularia* belonging to the cyanophyceæ. The fishy and oily odour occasionally met with may be attributed to *uroglena*, *dinobryon*, *bursaria*, *glenodinium*, *peridinium*, or *synura* among the protozoa, and to *volvox*, *endorina*, *pandorina*, or *dictyosphærium* belonging to the chlorophyceæ. In our own experience, *crenothrix* is a fruitful source of trouble, also *beggiatoa*, and certain species of *chara* which gives rise to an odour of sulphuretted hydrogen. In an unfiltered water, which has suddenly developed an odour, the offending organism will be found usually in great numbers as supplied to the consumers, whilst in a filtered water the offending organism will be more likely to be found in the filter-beds, the reservoirs, and even in the mains. Certain portions of water-

* Whipple. *The Microscopy of Drinking Water*. New York and London, 1899.

pipes, such as "dead ends," where the water is liable to become stagnant, present a greater chance of such development than elsewhere. Some ten years ago, Cheltenham was much troubled by a variety of the *Crenothrix polyspora* gaining access to their water-system and causing discoloration and odour in the water. Recently, in some camp-supplies in the vicinity of Aldershot, we have had trouble arising from crenothrix infection of pools and reservoirs; all the implicated waters contained small amounts of iron (Plates I. to V.).

In streams, into which sewage or trade effluents discharge, the following organisms constantly occur: *sphærotilus natans*, *beggiatoa alba*, *carchesium Lachmanii*, *leptomitus lacteus*; various oscillatoria, such as *O. brevis*, *O. tenessima*, *O. tenuis*, *O. antliaria* and *O. Frœlichii*. The first four are indifferently spoken of as the sewage fungus: beggiatoa appears as a white or grey velvety covering on the bottom of slow-running water containing sulphuretted hydrogen. We doubt whether this organism is as common as many imply, but the other three as tufts of filaments, or coloured cotton-wool-like masses adhering to stones, twigs, &c., in dirty running water, are very prevalent. A number of other organisms are frequently quoted as being especially characteristic of pollution; in our own experience the more important are certain forms of *Euglena*, *monas vulgaris*, *amphimonas fusiformis*, *eucomonas lacryma*, *colpidium*, *oxytricha fallax*, *peranema*, *paramœcium caudatum*, *trepomonas rotans*, and various species of *motricha*. The various filamentous algæ as represented by the oscillatoria are almost ubiquitous, the non-motile forms are found rarely in unclean waters. The majority of this form of life are undoubtedly Nature's scavengers, engaged in preparing the way for the appearance of higher forms of vegetable and animal life. We are not aware that any one of these various organisms are of themselves hurtful; they constitute for the most part convenient danger-signals as to deleterious matter existing in water in a less obvious form (Plates I. to V.).

The lower forms of animal life are only found in water containing organic matter in solution. This material may be derived from decaying vegetable matter. The higher forms of life do not denote necessarily impurity, but the presence of worms or of their ova and embryos is particularly objectionable, since they may be forms which can develop in the human body, and give rise to ill effects.

The most suspicious elements, which may be detected by a microscopical examination of water sediment, are those which point directly or indirectly to the waste products of man. Among the latter are cotton, wool, hair, and linen fibres, while the former include substances which leave the body in the fæces, owing to their indigestibility. Under this heading may be mentioned fat cells, starch grains, muscle fibres, various connective-tissue elements, shreds of membrane, epithelial cells, fragments of food, and the various parasitic worms, either as ova or mature forms. While attaching due importance to the search for and the recognition of all the above-named materials likely to be met with in sediments from waters, it must not be forgotten that an equal if not greater importance attaches to the search for and examination of the bacterial contents of water samples. Possibly a fuller experience of this branch of the microscopical examination of waters may not have quite justified the high hopes which its inception held out, still it contributes probably the most important information upon which we can form an opinion concerning the hygienic quality of any sample. This branch of the subject is discussed in the following section.

PLATE IV

[illegible] × 250
[illegible]
[illegible] × 250
[illegible]
[illegible]
[illegible]
7 Euglena. × 500
[illegible]
9 Synura. × 500
[illegible]
11 Dinobryon. × 500
[illegible]
13 Halteria. × 500

PLATE V

1 Paramecium × 250   4 Lemna × 1
2 Paramecium × 500   5 Cyclops × 25
3 Colpidium × 500   6 Daphnia × 25
7 Chara. × 70

THE BACTERIOLOGICAL EXAMINATION OF WATER.

It is practically impossible, in a work of this kind, to give a complete study of this difficult and complicated question; the most that can be attempted is a presentation of the more important facts, and the outline of a working scheme for the routine biological examination of waters, upon which the student, by a further study of the special literature * of the subject, can build a more complete and more elaborate procedure. It is also assumed that no one will attempt the bacteriological examination of a water sample who has not acquired a knowledge of the necessary experience and technique in a suitably equipped laboratory, under the guidance of a competent teacher. For these reasons it is deemed unnecessary either to describe the apparatus to be found in every laboratory, or to enter into details of the comparatively simple technique used in the routine methods of bacteriological work.

We would say, however, that the bacteriological examination of a water sample constitutes an essential complement to its chemical analysis, and that the latter without the former affords at best but an imperfect gauge as to the freedom of a water from organic contamination. Bacteriological examinations of water samples are undertaken mainly either for testing the efficiency of filter-beds, or for the direct detection of pollution from manure or sewage. This information, upon which such opinions or conclusions can be based, is practically of the following three kinds :—(1) A quantitative estimation of the number of micro-organisms present in the sample of water under examination; (2) the detection of micro-organisms not necessarily hurtful to man, but whose presence and origin imply that the sample is more or less contaminated with fæcal or manurial pollution; (3) the isolation and identification of actual disease-producing organisms. The smaller the volume of water in which the micro-organisms under the second and third headings can be detected, the greater the pollution, and *vice versa.*

From what has been said it is evident that a bacteriological, like a chemical, examination consists of quantitative and qualitative analyses. But while in a chemical examination the quantitative analysis is the more important of the two, the reverse is the case as regards a bacteriological examination.

The Collection and Transmission of Samples.—This constitutes a very important procedure, and any carelessness displayed is liable to vitiate seriously the results. The sample should be collected in glass bottles with glass stoppers, previously sterilised by steaming to 150° C. for three hours; if sterilisation cannot be effected, the bottles may be cleaned sufficiently for all practical purposes by washing with a little pure sulphuric acid, all traces of acidity being finally removed by thoroughly rinsing the bottle with some of the water to be examined. In the case of a river or lake the bottle should be plunged below the surface before the stopper is removed; in this way a sample of the main body of the water will be obtained. In some cases, as when investigating an outbreak of cholera, it is desirable to examine the surface water. This specimen should be collected in a separate bottle and labelled accordingly. If the source of supply is a "service water," the tap should be opened and the water allowed to run to waste for a few minutes before the specimen is collected; in this way local impurities will

* The reader is advised to consult the following works: *The Examination of Waters and Water Supplies*, by J. C. Thresh, Lond. 1904; also *The Bacteriological Examination of Water*, by W. H. Horrocks, Lond. 1901; also *The Bacteriological Examination of Water Supplies*, by W. G. Savage, Lond. 1906.

be washed out of the tap, and the water which has been standing in the service pipes will be removed. It is always desirable, in the case of a "service water," to obtain a specimen direct from the mains. In the case of a well not in constant use it is usually found that the sample obtained, on first pumping, contains a very large number of micro-organisms; so that to gain an idea of the condition of the water which enters the well from the surrounding strata, it is advisable to pump continuously for several hours before collecting the sample for examination. After the specimen has been obtained the glass stopper should be carefully tied down with a little oiled silk. When the source of supply is a shallow stream, such as the feeder of an upland surface water, it is often impossible to use a bottle without disturbing the sediment. Under these conditions a test-tube with stout walls may be drawn out just below the open end; the contained air is then removed by prolonged heating, or more simply by allowing a little water to enter the tube, which is then heated until steam escapes, when the point is rapidly sealed. The fine point of such a tube should be placed under the surface of the stream, and then the tube opened by breaking the point with a pair of sterile forceps. The water will run in and fill about two-thirds of the tube; the point is then sealed up by heating with a spirit-lamp. When examining lakes and rivers it is often desirable to take specimens from various depths. This may be done by using Miquel's apparatus, which consists of a glass bulb weighted below and suspended by a wire marked in feet or metres. The neck of the bulb is drawn out to a fine point and bent like a swan's neck. A second wire, running in eyes on the suspension wire, is bent at the end into a loop, which is placed round the neck of the bulb. When the required depth is shown on the suspension wire, the second wire is pulled sharply so as to break the neck and allow the water to enter the bulb. The same result may be obtained by weighting the ordinary glass bottle and supporting it by means of strong string knotted at intervals of a foot. A second string is tied round the glass stopper, which should be partially loosened so as to be easily pulled out when the required depth is reached. The samples should be examined immediately after collection; if this cannot be done they must be packed in ice for transmission to the laboratory. It has been found that when the temperature is kept below 5° C. there is practically no increase in the number of micro-organisms in the water. This effect appears to be due, not to an immobilising of the bacteria, but rather to the fact that cold acts differently on certain species, so that the deaths of some organisms are balanced by the birth of others.

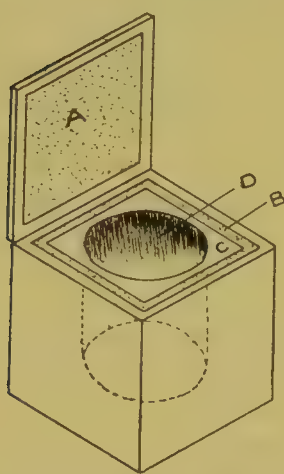


Fig. 5.—Box for Carriage of Water Sample.

A. Lining of felt.
B. Asbestos and felt lining.
C. Space for ice.
D. Space for bottle containing sample.

For the transmission of samples intended for bacteriological examination, special boxes or carriers are employed usually; these contain one or more glass-stoppered bottles of about eight-ounce capacity, fitting into a tin-lined receptacle, and into which they are carefully secured by a close-fitting lid. This tin case containing the bottle or bottles is surrounded by a metal receptacle for holding ice, this again being surrounded by a thick layer of asbestos and felt, the whole being contained in a strong wooden box or case, having a well-adjusted felt-lined lid, and capable of being fastened securely

and locked (Fig. 5). In transmitting these carriers to the laboratory, it is of the first importance to do so by the most expeditious route, so as to avoid all possible delay. Full particulars as to the nature and source of the sample should invariably accompany the carrier, as without such information it is difficult to give a satisfactory opinion regarding its hygienic condition.

The Quantitative Bacteriological Examination.—The determination of the number of micro-organisms in a known volume of water is effected mainly by cultures on solid media, such as gelatin or agar. The method consists in adding varying quantities of the water to tubes of gelatin or agar which have been melted by immersion in a water-bath ; each of these is then thoroughly mixed and poured with suitable precautions into a sterile Petri-dish, and solidified as rapidly as possible. These water-plates are then incubated, the gelatin at 20° C., and the agar at 37° C. Each organism present, capable of development under the existing conditions, develops into a mass or colony of bacteria, visible to the naked eye, and as such readily counted. The total number of colonies found gives the number of organisms capable of development in the medium used, and at the particular temperature of incubation.

The water to be examined should be shaken thoroughly for a few minutes ; in this way all clumps of bacteria will be broken up and each organism will produce only one colony when it develops in the Petri-dish. The next step is to determine the amount of water which can be used for each plate, as it is necessary that each micro-organism shall have sufficient room to develop without touching its neighbours. The simplest method of arriving at an idea of the number of bacteria present in the water is to remove $\frac{1}{20}$th c.c. of the water from the shake-bottle and deposit it on a cover-glass ; then by staining and counting the microbes on the cover-glass it is possible to determine approximately the number of micro-organisms present in a c.c. of the water. When working with Petri-dishes having a diameter of four inches, it is best to use such an amount of water as will give not more than 300 colonies in each plate. If the water contains a large number of organisms it should be diluted with sterile tap-water. In order to measure the calculated amount of water required for each plate, accurately graduated pipettes must be used. One c.c. pipettes graduated in $\frac{1}{100}$ths are most useful. Each pipette must be thoroughly cleaned ; the upper end is then plugged with cotton-wool and the lower end placed in a sterile test-tube, the mouth of which is firmly plugged with cotton-wool. The test-tubes and pipettes are sterilised at 150° C. for three hours, and kept in metal boxes until required for use. The Petri-dishes, wrapped in thin paper, are also sterilised in the same manner. For enumeration of the colonies, it is convenient to count with the plate on a dark background, dividing the area by lines marked on the plate itself. When plates are very crowded, it may be possible to count colonies in only a few segments, deducing the total bacterial content from these data. Apart from difficulties due to overcrowding, enumeration of colonies on gelatin plates is often impossible owing to the presence of types which more or less rapidly liquefy this medium.

In tropical climates it is often impossible to use gelatin. During many months of the year, the air temperature is above the melting-point of gelatin, consequently the plates remain fluid and the micro-organisms are not kept apart so as to permit a proper isolation of the colonies. Under these conditions agar-agar must be used as the nutrient medium. Agar tubes are melted and seeded with the water after they have cooled down to 40° C. ; the mixture of water and agar is then poured out, as before described, into

Petri-dishes and allowed to incubate at the prevailing temperature. A simpler method is to pour out the melted agar into a Petri-dish and allow it to set; the calculated amount of water is then introduced by means of a pipette, and the fluid evenly distributed over the surface of the agar by means of a platinum spreader. It must, however, be borne in mind that the higher temperatures which obtain in tropical climates are prejudicial to the development of water organisms, and consequently the number of resulting colonies will be much smaller than on gelatin or other plates incubated at from 20° to 22° C. At whatever temperature the plates are incubated they should be inspected daily, and the colonies which develop counted. As a rule, it will be found that there is no material increase in the number after the fifth day, and if possible the plates should be kept for this period. But if many liquefying organisms are present, gelatin plates will be destroyed by the third or fourth day, occasionally sooner.

In regard to the number of micro-organisms present in waters derived from different sources, no hard-and-fast standards can be enunciated. A dirty water will contain many more organisms than a pure water, but the number in a pure supply may vary from 50 to 500 per cubic centimetre. When judging the efficiency of water-filters, Koch laid down as a standard that filtration could not be accepted as satisfactory if the number of micro-organisms exceeded 100 in each cubic centimetre of filtrate. As a working basis this standard is adhered to by many observers. The value and importance attaching to the enumeration of the bacteria present in a given quantity of water has been variously appraised. For our own part we do not think that, in itself, it furnishes information of any great importance. We are forced to this conclusion from the fact that the nature of the medium, its reaction, the duration and temperature of incubation, are all important factors in the development of water bacteria. It is well known that the reaction of the media used exercises a marked influence on the number of micro-organisms which develop. Until some authoritative standard is arrived at, and all observers agree to adhere to media of that standard reaction, it is difficult to compare results. The American workers recommend all media used in this class of work to be +1·5, that is, acid to the extent of 1·5 per cent. of normal acid, using phenol-phthalein as the indicator. The tendency in this country is to use a + 1 per cent. standard, and is the reaction usually employed by ourselves.* Again, there is no uniformity of practice as to duration and temperature of incubation. Some count only the colonies visible on the second day, others those visible on the third, fourth, or even fifth days; some enumerate only colonies visible to the naked eye, others use a lens or low power of the microscope for counting. It seems desirable to be very careful about stating that a given water contains a certain number of organisms per cubic centimetre, as any accurate determination of the kind is practically impossible. The most that should be said is, to state that 1 c.c. of the sample has yielded so many organisms on such and such medium, of a stated reaction, after so many days' incubation at a given temperature, taking care to add whether the colonies included only those visible to the naked eye, or all visible under a certain degree of magnification.

On the basis of a quantitative bacteriological estimation, the only sound way to judge a water-supply is to examine it systematically and periodically,

* NOTE.—The mode of preparing and standardising various culture media is described in the Appendix, at the end of this volume. Unless otherwise mentioned in the text, the composition of media referred to in this section may be assumed to be as given in the Appendix.

under comparable conditions of media and temperature, and duration of incubation. In this way, local standards for comparison will be obtained which will have great practical value.

Qualitative Bacteriological Examination.—In the hygienic examination of a water sample no attempt can be made to isolate and recognise all the various kinds of bacteria present, many being normal inhabitants of ordinary water; on the contrary, the most we can do is to regard this most important examination as embracing the isolation and recognition of organisms not necessarily hurtful, but which from their origin are especially liable to be associated with contamination, coupled with the isolation and identification of actual disease-producing organisms. Owing to the inherent difficulties in the way of isolating actually specific disease-producing bacteria from a water sample, it must be admitted that in the greater number of cases we have to rely mainly upon the detection of organisms associated with fæcal or manurial contamination, and although the various methods which have been suggested for this purpose, are by no means perfect or completely satisfactory, still, if properly conducted, they may be relied upon to detect pollution, even to the extent of one part of recent sewage in a million parts of water. When the pollution is less than this, or when the contamination is far from recent, the bacteriological results usually suffice to raise grave suspicions of pollution, and, if supplemented by an inspection of the source of the water or a knowledge of its history, are sufficient to justify a definite opinion being formed and given. In the light of our experience, the qualitative bacterial method of examination of a water is about a thousand times more delicate than the chemical method.

A variety of procedures have been proposed for obtaining an indication of the presence or absence of organisms rarely present in waters of known purity, but which are present invariably in sewage-polluted samples. These procedures are based mainly upon the principle of either placing definite volumes of the water into media or under conditions which retard or inhibit the growth of the ordinary water organisms, and yet allow the sewage forms to develop, or placing the water sample into media which foster the growth of organisms of intestinal origin if present, rather than inhibiting the development of the ordinary water bacteria. The most practical, comprehensive, and, in our opinion, the most generally useful method is Thresh's adaptation of one put forward originally by MacConkey and Hill.* This consists in adding to varying quantities of the water sample a special medium, namely, bile-salt-glucose-peptone-litmus solution, and incubating at 42° C. for forty-eight hours. The method may be defined as being a fostering procedure *quâ* sewage organisms, and possibly also inhibitory as to other forms of microbes. For the routine examination of waters, a concentrated stock solution should be prepared, made as follows: Sodium taurocholate, 15 grammes; glucose, 15 grammes; peptone, 60 grammes; litmus solution, a sufficiency to give a deep purple tint; distilled water, 1 litre. This is boiled and filtered, and then, subject to certain dilutions as detailed hereafter, run in varying quantities into each of a number of clean test-tubes, in which is also a small inverted glass tube ($1\frac{1}{2}$ inch by from $\frac{1}{4}$ to $\frac{1}{2}$ inch). The outer tubes, after addition of the solution and plugging with cotton-wool, are sterilised for fifteen minutes at 100° C. on three successive days. The degree of dilution of this stock solution required depends absolutely upon the volume of water sample which is to be added to it, as it is desirable that in each case the final dilution may contain approximately the same

* MacConkey and Hill: "Bile Salt Broth," *Thompson-Yates Laboratories Reports*, 1900-1.

proportion of the bile-salt and other constituents. For the practical application of this medium in the examination of waters, it is desirable to have the test-tubes of two sizes, namely, large ones measuring 8 inches by 1 inch, and smaller ones 6 inches long and ¾ inch in diameter. With them the following dilutions have been found to work well :—

(*a*) Into the large-sized tubes place 30 c.c. of the concentrated stock solution of bile-salt-glucose-peptone-litmus solution, and sterilise in the usual way. To these 50 c.c. of the water to be examined may be added and then incubated as explained.

(*b*) Dilute one volume of the concentrated stock solution with half its volume of distilled water, place 10 c.c. of this diluted solution into each smaller sized test-tube and sterilise. To each of these 10 c.c. of the water sample may be added and then incubated as above.

(*c*) Dilute one volume of the concentrated stock solution with an equal volume of distilled water, place 10 c.c. of this diluted solution into each of the smaller sized test-tubes and sterilise. To each of these 5 c.c. of the water sample may be added and then incubated.

(*d*) Dilute one volume of the concentrated stock solution with two volumes of distilled water, place 10 c.c. of this diluted solution into each of the smaller sized tubes and sterilise. Each of these may then receive 2 c.c. or less of the water under examination and be incubated.

By this method we have a series of test-tubes containing varying strengths of the bile-salt solution, and, by the addition of varying volumes of the water to be examined, so diluted that they approximately all contain the same proportions of original constituents. Experience shows that the micro-organisms which can grow in this bile-salt-glucose-peptone solution after incubation are divisible into three main classes, namely : (1) Those which ferment the medium to the formation of both acid and gas ; (2) those which produce acid but no gas ; and (3) those which produce neither acid nor gas, but merely a turbidity. Of course if the contents of the tubes remain clear, it is evident that the micro-organisms present in the added water are incapable of growing in this particular solution ; as a matter of fact, this is not infrequently the case with pure waters.

Now, what is the interpretation to be placed upon these various results ? We may say, at the outset, that the organisms which merely grow, but fail to produce either acid or gas in this medium, have little significance in the hygienic examination of water, as practically none of them can be said to be of fæcal origin. Interest, therefore, centres chiefly in the first two classes, as they are, for the most part, organisms of intestinal type, more especially those of Class I., that is, producers of both acid and gas—as these include all the more important organisms found in sewage. Moreover, as those coming under the second class—that is, producers of acid only—are invariably associated with others belonging to Class I., it is rare to find the production of acid only in this medium, the practical deduction being that it is unnecessary to examine a water sample further if, after being manipulated and incubated as explained, it is found not to contain micro-organisms capable of producing both acid and gas in the bile-salt-glucose-peptone solution.

The chief micro-organisms, more or less associated with sewage and liable to be met with in a water sample, and which ferment the bile-salt-glucose-peptone solution, are given in the following table :—

Group I. Producing acid and gas.	Group II. Producing acid but no gas.
B. coli communis.	B. typhosus.
B. acidi lactici.	B. dysenteriæ.
B. lactis aerogenes.	B. choleræ.
B. capsulatus.	B. pyogenes fœtidus.
B. neapolitanus.	Streptococci.
B. icteroides.	Staphylococci.
B. psittacosis.	
B. proteus.	
B. cloacæ.	
B. enteritidis (Gärtner).	
B. paracolon.	
B. paratyphosus.	
B. of hog cholera.	
B. of epidemic jaundice.	

In addition to the above-named organisms, it must be clearly understood that a certain number of micro-organisms exist in water, often of undoubted purity, which are capable of producing acid in this medium, and occasionally minute quantities of gas. This fact emphasises the need of recognising these reactions merely as preliminary steps in the inquiry as to the existence or absence of objectionable or hurtful types of bacteria in any given water sample, and that no hasty conclusions are to be drawn from the production of gas, and still less so from the mere acidification of the medium after inoculation with varying quantities of water. For these reasons it is imperative to continue the investigation before deciding that the water is polluted. This further investigation involves the plating out in gelatin, or upon lactose-agar or any other medium suitable for the isolation and differentiation of specific species. We deem it necessary to lay stress upon this warning, as some workers are tempted to regard these preliminary reactions as specific evidence of pollution. They certainly are not that, though in nine cases out of ten the production of acid and gas in any of the tubes is strong presumptive evidence of the presence of organisms in the water which have been derived from sewage or manurial matter.

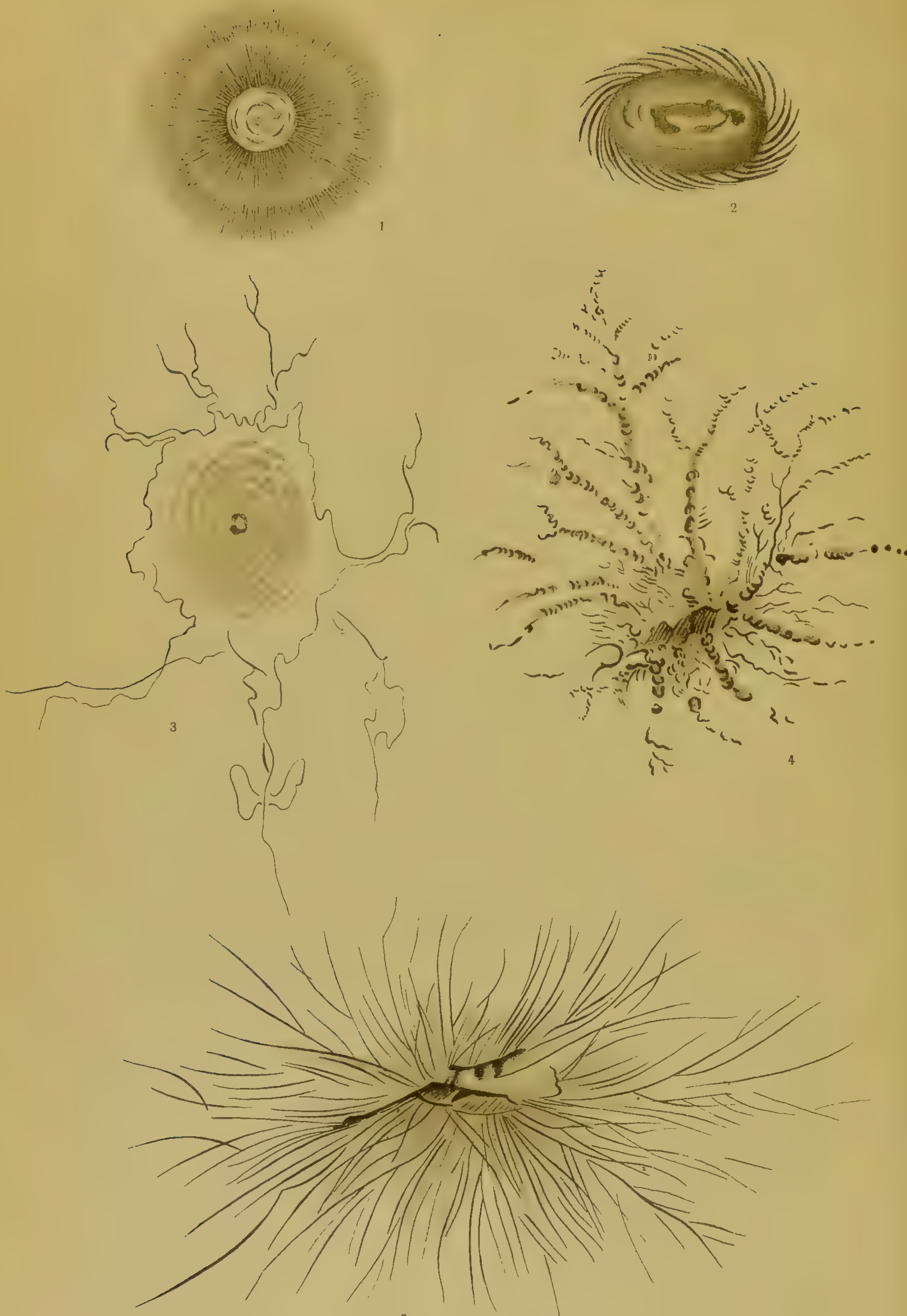
Assuming, then, that one or more of the bile-salt tubes, after inoculation with the water sample, have shown acid and gas production, it is then necessary to plate out for the exact differentiation of species. This is best done by making a series of gelatin plates from the tube or tubes which have given the reaction after inoculation with the smallest volume of the water sample. The colonies which develop on the plates must then be examined, any suspicious ones fished off on to agar slopes, and from these cultures further subcultures made in the various media, to be mentioned, to establish the identity of the particular micro-organisms isolated. The various organisms liable to be found in water capable of producing gas in glucose-bile-salt solution, and consequently likely to develop on the various plates set from the original water-seeded bile-salt-glucose-peptone tubes, may be divided into four great groups. In the first are a number of motile organisms of a somewhat unstable biological equilibrium, which liquefy gelatin, produce acid and gas in glucose, maltose, sucrose and galactose, but not in lactose, lævulose, arabinose, raffinose, mannite, sorbite, dulcite, dextrin, starch or inulin, curdle milk somewhat slowly, rendering it acid, and commonly produce indol in peptone solutions. These organisms represent the great *proteus* family, and the type is the *B. proteus vulgaris*. In the second group are motile bacteria, producing gas and acid in glucose, lactose, galactose,

lævulose, maltose, arabinose, raffinose, mannite, sorbite, dulcite and dextrin, but not in sucrose, starch or inulin, curdle milk rapidly, with no peptonisation of the clot, and produce commonly indol in peptone, but do not liquefy gelatin. These organisms are the *B. coli communis*, derived indifferently from the alimentary canal of man and animals. In the third group are non-motile bacteria, not liquefying gelatin, which not only curdle and render milk acid, but ferment glucose, lactose, galactose, lævulose, maltose, arabinose, raffinose, sucrose, mannite, sorbite, dextrin and starch, they do not ferment dulcite or inulin. The type of this group is the *B. lactis aerogenes*. In the fourth group we find motile bacteria, fermenting all the sugars except lactose and sucrose, not liquefying gelatin, and not clotting milk, but rendering it finally alkaline. These organisms are the intermediates of the colon-enteric series, and include such species as the *B. enteritidis* of Gärtner, the various paracolons and the paratyphoids. Indol production is variable with this series, but not infrequent.

It will be apparent from this summary that the liquefaction or non-liquefaction of the gelatin constitutes a broad line of differentiation between the first group and the others; but it must be borne in mind that all the liquefying colonies on a gelatin plate prepared in this way are not necessarily members of the proteus group, though, as a matter of fact, owing to the bile-salt apparently keeping back or inhibiting the growth of the common water organisms, which are also capable of liquefying gelatin, the greater number will be found to belong to the great proteus family. Members of this group are invariably found in sewage and in dirty waters, especially where surface washings from manured land gains access to a water-supply; consequently their presence in great numbers constitutes a suspicious piece of evidence. On the other hand, one occasionally meets with members of this group in undoubtedly clean and safe waters, but in these cases there is usually a complete absence of members of the other three groups; therefore, in attempting to appraise them at their proper hygienic value, one must have regard to all the facts, more particularly taking into consideration their association or non-association with members of the other groups. In the same way it must not be assumed hastily that all the non-liquefying colonies are necessarily either *B. coli* or *B. lactis aerogenes*, or one of the various paracolons and paratyphoids; the exact determination of species can be made only by careful subculturing in a variety of media, and a critical noting of their morphology and other features. Precisely the same remarks apply to colonies which may develop on gelatin or other plates inoculated from bile-salt-glucose solution, in which acid, but no gas, has formed after the addition of some of the water sample. Some of these may liquefy gelatin (*e.g.*, the cholera vibrio), and some will not. Each one of the resulting colonies on these plates will need to be judged upon its individual features as manifested by subculture in various media. While no detailed description can be given of all the possible microbial forms which may be met with in the bacteriological examination of water, still the following short statement, regarding the chief varieties which have a dominant significance in this branch of hygienic investigation may be of use. The composition and mode of preparation of the various media mentioned are detailed in the Appendix.

B. proteus, or, as it is often called, *Proteus vulgaris*, is a small bacillus with rounded ends, often in pairs or in chains; it is motile, and not spore-bearing; grows at 42° C., but better at 20° C. It stains with Gram's method. The colonies on gelatin plates, after twenty-four hours, are delicate granular films of irregular shape; in forty-eight hours they begin

Plate VI.



1 and 2 Proteus vulgaris
3 and 4 Proteus zenkeri
5 Proteus mirabilis

to liquefy, and appear as punched-out circles. The colonies in the early stage are usually circular; the margin may show a fine, bristly formation, or spindle-shaped processes tending to run out all over the gelatin. When grown as a gelatin-stab culture, the medium is rapidly liquefied in a funnel-shaped manner. In broth the growth is diffuse, without pellicle; on agar, the growth is not characteristic, being moist and greyish white; on potato it is moist but yellowish. In media containing glucose, sucrose, maltose, or galactose there is production of both acid and gas, but in lactose and the other carbohydrates there is no fermentation. In milk, clotting occurs in about two days with formation of acid, and in peptone solution there is usually production of indol after about five days. Closely associated with this organism are two other varieties of proteus, namely, *P. Zenkeri* and *P. Mirabilis*. These differ from the common proteus in not fermenting glucose or other sugar media. In general character, their surface colonies are suggestive of moulds and, under a low power, present many marginal processes; zooglœa masses are commonly seen, occasionally threads and involution forms are noticeable; gelatin is liquefied slowly. As suggestive of pollution, these two proteus forms have not the same significance as *P. vulgaris* (Plate VI.).

B. cloacæ.—This is a gelatin-liquefying organism, widely distributed and not uncommon in sewage-tainted waters. It may be described as an actively motile, Gram-negative, facultative anaerobic bacillus, fermenting practically all the carbohydrates and alcohols, except dulcite; it produces acid and clot in milk and not infrequently indol in peptone solution. Since first described by Jordan, this micro-organism has been the subject of some controversy, and by some considered identical with *B. coli*, *B. acidi lactici*, and *B. lactis aerogenes*; this it certainly is not. Its most distinguishing feature has been shown by MacConkey * to be what is known as the Voges and Proskauer's reaction. This reaction is the production of a rose-red colour in the closed arm of a fermentation tube containing glucose broth when standing twenty-four hours after the addition of potash; to what the colour is due is not known, but it appears to be a feature pretaining only to the *B. cloacæ* and to the *B. lactis aerogenes*, serving to distinguish them from a number of micro-organisms with which there has been a tendency to confuse them.

B. lactis aerogenes.—This is a non-motile rod decolourising with Gram's stain. On gelatin plates the surface colonies are porcelain-white in colour, and more or less circular; the deep colonies are round, granular, and yellowish brown in tint. On agar, the growth is opaque and porcelain-white. In gelatin-stab culture, the growth is free along the line of inoculation, with a nail-head expansion on the surface; the gelatin is not liquefied. In milk, there is coagulation usually within forty-eight hours, with marked acidity. In broth, there is uniform turbidity, and not infrequently some pellicle. When grown in the various sugars, such as glucose, lactose, sucrose, maltose, and in the alcohol mannite, there is marked fermentation with gas production; it does not touch dulcite. In peptone and salt solution there is usually some indol produced by the fifth day, but some strains fail to make indol. Perhaps the most characteristic cultural reaction of this micro-organism is on potato, where it produces a white, creamy growth, permeated with gas bubbles. Like the *B. cloacæ*, this bacillus gives Voges and Proskauer's "Kalilauge-roth-reaktion." This organism is common in milk, fæces, and dirty water; it is liable to be mistaken for

* MacConkey: "Lactose-fermenting Bacteria in Fæces," *Journal of Hygiene*, vol. v. p. 333.

the common colon bacillus, from which, however, it is clearly culturally distinct.

B. coli communis.—This important micro-organism appears as a very short bacillus, often resembling a coccus. It is usually motile, but occasionally strains are found to be not so. As a rule, it possesses one to five flagella, but owing to their brittleness these are difficult to stain. There is no spore formation. This micro-organism stains readily with ordinary basic dyes, but is decolourised by Gram's method. On gelatin plates, the deep colonies are not unlike those of *B. lactis aerogenes*, being oval or circular in shape and brown in colour. After twenty-four to forty-eight hours, the surface colonies are thin, bluish grey, transparent vine-leaf expansions with an irregular margin. Those of *B. lactis aerogenes* never show this expansive growth or the crenated margin, being more fleshy or thick. The ridges and surface of the *B. coli* colonies almost invariably show tracings of furrows running from the centre to the periphery, while at times fine wavy lines parallel to the margin are to be seen. These features of the surface gelatin colonies are usually sufficient to differentiate it from the *B. lactis aerogenes*, whose surface colonies are coarser, less expanded, and altogether lacking in that delicate mother-of-pearl-like appearance so characteristic of the common colon bacillus. The gelatin is not liquefied. As a gelatin stab, there is a nail-head-like surface expansion and marked growth along the line of inoculation. When grown as a streak on a gelatin slope, the growth is white, broad, and marked by a crenated margin. On agar, the growth is not characteristic. In broth, a general turbidity results, but usually no film or pellicle. On potato, the growth commonly takes the form of a brownish yellow layer. Milk is coagulated usually within forty-eight hours after incubation at 37° C. with formation of acidity. Indol production is almost invariable in peptone and salt solution, after five days' incubation at 37° C. When grown in media containing glucose, lactose, maltose, mannite, lævulose, galactose, arabinose, raffinose, sorbite, dulcite, or dextrin, there is free production of acid and gas; some few strains are said to ferment sucrose, but in our experience the true typical *B. coli communis* derived from the human intestine does not split cane-sugar. Theobald Smith lays stress upon the amount of gas produced and upon the ratio of H to CO_2 as of value in separating *B. coli* from allied forms. In dextrose broth, *B. coli* produces H to CO_2 as 2 to 1. When grown in the two media suggested by Proskauer and Capaldi, there is an acid growth in No. 1 after twenty-four hours' incubation at 37° C., while in No. 2 medium there is a similar growth, but the reaction is either unchanged or rendered faintly alkaline. Some writers have laid stress upon the reaction obtained with *B. coli communis* when grown in glucose-agar coloured with neutral red, when the magenta red is changed to a yellowish green fluorescence after two days' incubation at 37° C. In the majority of cases this does occur, but we are indisposed to regard it as in any way specific or characteristic of this particular micro-organism. The foregoing description gives the chief characteristics of the typical *B. coli* as commonly met with in dirty water, in sewage, and from human or animal excrement, but it must be borne in mind that varieties are not uncommon which fail to conform strictly to the type, which is that of the organism originally described by Escherich. The chief departures from the type are inability to produce indol and to bring about coagulation of milk within three or four days. We have never come across any of these aberrant forms in dirty water without finding them associated with others which conform strictly to the classic type; it is the association or not with organisms undoubtedly *B. coli communis*

which must guide the worker in the formation of an opinion as to whether he has isolated a presumably fæcal organism or not.

Among other important micro-organisms liable to be mistaken for the *B. coli* are the *B. acidi lactici* of Hüppe, the *B. neapolitanus* of Emmerich, the *B. pneumoniæ* of Friedländer, and the *B. capsulatus* of Pfeiffer; all these, at times, have been found in water-supplies. The surface colonies of these organisms on gelatin present very little resemblance to those of the common colon bacilli, being more opaque, less expansive, and more viscid. They do not liquefy gelatin and further resemble *B. coli* in being Gram negative. It is in respect of their cultural features in the carbohydrates and alcohols that the chief confusion arises, but distinctions can be made by noting the following points. The *B. acidi lactici* resembles the *B. coli* in not fermenting sucrose, but differs from it in failing also to split dulcite. The *B. neapolitanus* ferments both sucrose and dulcite, in addition to the various other carbohydrates. *B. pneumoniæ* ferments all the carbohydrates, while *B. capsulatus* only fails to make acid and gas in dulcite; it, however, presents the "Kalilauge-roth-reaktion" of Voges and Proskauer. The last two micro-organisms are morphologically distinct from the two first named, in that they usually have a capsule.

The Intermediates.—Under this heading are embraced a number of micro-organisms which, from their cultural reactions, occupy an intermediate position between the typical *B. coli communis* and the *B. typhosus.* They are motile rods, staining readily with ordinary dyes, decolourising by Gram's method, not liquefying gelatin, and producing on that medium surface colonies which present many points of resemblance to those of the common colon bacillus. Their characteristic features are an ability to ferment all the carbohydrates and alcohols except lactose and sucrose, failing to clot milk, but rendering it finally more or less alkaline. Typical members of this group are the various paracoli bacteria, the paratyphoids, the *B. psittacosis*, the *B. icteroides*, the bacillus alleged to be the cause of epidemic jaundice, and the *B. enteritidis* of Gärtner, an organism which has been associated with certain forms of diarrhœa and acute infection presumably due to contaminated or degraded meats. The occurrence of members of this group in water samples is, in our experience, rare, but an appreciation of their biological position, and as possible fermenters of bile-salt glucose broth is necessary on the part of all those who employ this medium in the routine examination of waters.

B. typhosus.—This, the most important representative of the group which produce acid but no gas in bile-salt glucose-peptone solution, is a highly motile bacillus without spores, and decolourising by Gram's stain. It possesses from eight to twelve long wavy flagella disposed all round the bacillus. It grows at 42° C., but better at 37° C.; it fails to do so at 0° C. It is killed by an exposure to 65° C. for ten minutes, and by an exposure of less than a minute to 80° C. On gelatin plates the deep colonies are granular, and round or oval in shape. The surface colonies grow slowly, requiring seventy-two hours usually before they show their characteristic appearances as thin bluish grey films with an irregular margin; under a low power, markings are seen which look like ridges and valleys running irregularly from the centre to the periphery—in fact, these colonies resemble closely those of the *B. coli* and some other members of that group. Occasionally the surface colonies of the *B. typhosus* are without the "relief-map" appearance, and merely finely granular, resembling a thin film of glass. The gelatin is not liquefied. When stabbed into gelatin, the surface growth is like the plate-surface colonies, and along the line of inoculation there is a fine growth

of discrete white points or masses. If streaked on a gelatin slope, a white, narrow growth develops along the line of inoculation with an irregular margin, but the whole growth is less marked than the corresponding culture of *B. coli.* The main point of distinction between the respective growths of these two micro-organisms upon gelatin is the relative slowness of development on the part of the enteric organism. On agar, the growth is not characteristic, being moist and grey. On potato, a smooth glistening film forms, which is so devoid of colour and structure as to be very difficult of detection with the naked eye. In broth, there results a diffuse cloudiness without pellicle. In glucose, maltose, lævulose, galactose, raffinose, mannite, sorbite and dextrin, the *B. typhosus* produces acid but no gas, while in lactose, sucrose, arabinose, and dulcite there is not even acid. After a week or more of incubation at 37° C. in peptone and salt solution, there is no formation of indol. Milk, even after a fortnight's incubation at 37° C., is unchanged to the naked eye, but there is invariably the production of some acidity. In the media suggested by Proskauer and Capaldi (*see* Appendix) the reaction of the *B. typhosus* is typical, namely, after twenty-four hours' incubation at 37° C. no growth in the No. 1, but a marked acid growth in the No. 2. In these reactions it will be seen this micro-organism differs markedly from the common colon bacillus. If some enteric serum is available, valuable evidence as to identity is obtainable by noting its agglutinability or not.

Closely allied to the *B. typhosus* in many of its cultural reactions is the *B. dysenteriæ* and certain associated species. From the examination of a considerable number of *B. dysenteriæ*, we are disposed to lay stress, as a means of diagnosis, upon the facts that the *B. dysenteriæ* is never so motile as the enteric organism; it, further, never makes acid in mannite, sorbite, or dextrin, it does not agglutinate with an enteric serum, and, moreover, tends to produce alkalinity in milk on prolonged incubation. In all its other cultural reactions it practically is identical with those described as typical of *B. typhosus.* The various paradysentery bacilli, or, as we prefer to call them, the *B. typhosi simulantes,* offer many points of resemblance to the enteric organism, and as they are not infrequently isolated from waters, their due discrimination is important. Judging by our own experience, these micro-organisms differ from the true *B. typhosus* only in that they fail to agglutinate with enteric sera, give acid in arabinose but fail to do so in sorbite; they are at best but feebly motile, usually produce indol, and render milk faintly alkaline. On the other hand, they stand apart from the *B. dysenteriæ* in that they are non-pathogenic to rabbits and guinea-pigs, are not readily agglutinated with dysenteric sera, produce acid in mannite, arabinose and dextrin, as well as indol in peptone and salt solution.

Apart from these, there are many organisms which present superficial resemblances to the *B. coli communis* and the *B. typhosus,* and whose isolation from water samples may give rise to difficulties. The more common are the atypical members of the coli group, reference to which has already been made. The *B. acidi lactici* produces surface colonies somewhat like those of the enteric and colon bacilli; but it is a spore-bearing organism, coagulating milk, producing indol and forming gas in all the carbohydrate media except sucrose, dulcite, starch, and inulin. Another micro-organism which may give trouble is the *B. ureæ,* and occasionally found in dirty water. Its surface colonies on gelatin are of the colon-enteric type, but it does not react to either typhoid or dysenteric sera, and rapidly converts urea into ammonium carbonate. The *B. sulcatus* is a common water organism which occasionally is mistaken for both *B. coli* and *B. typhosus* on

gelatin plates in their early stage. It can be recognised usually by the fact that the colonies acquire a yellow colour. Their subcultures are distinguished readily by the facts of not coagulating milk, producing no indol, and forming no gas in glucose. Similar difficulties may arise with another common water organism, namely, the *B. fluorescens non-liquefaciens*, but its fluorescence is characteristic; it produces no gas in the various sugars, and does not coagulate milk. The possible presence of this and other similar micro-organisms in a series of plates set from a water culture should be borne in mind; in no case should an opinion as to identity be formed hastily, or from an examination of a mere surface or other colony; each suggestive colony must be fished off on to an agar slope, and the final judgment formed only upon a critical analysis of the subcultural reactions in various media, more particularly fermentation reactions in glucose, lactose, sucrose, mannite, and dulcite, with possibly the Voges-Proskauer reaction To facilitate the differential diagnosis of common fæcal and other organisms, the accompanying table of reactions in various media may be found useful.

	Glucose.	Lactose.	Sucrose.	Maltose.	Lævulose.	Galactose.	Arabinose.	Raffinose.	Mannite.	Sorbite.	Dulcite.	Dextrin.	Starch.	Voges-Proskauer Reaction.
B. coli communis .	+	+	—	+	+	+	+	+	+	+	+	+	—	—
B. acidi lactici .	+	+	—	+	+	+	+	+	+	+	—	+	—	—
B. lactis aerogenes .	+	+	+	+	+	+	+	+	+	+	—	+	+	+
B. cloacæ . .	+	+	+	+	+	+	+	+	+	+	—	+	—	+
B. proteus vulgaris .	+	—	+	+	—	+	—	—	—	—	—	—	—	—
B. neapolitanus .	+	+	+	+	+	+	+	+	+	+	+	+	—	—
B. capsulatus . .	+	+	+	+	+	+	+	+	+	+	—	+	+	+
B. pneumoniæ .	+	+	+	+	+	+	+	+	+	+	+	+	—	—
B. enteritidis of Gärtner . .	+	—	—	+	+	+	+	+	+	+	+	+	—	—
B. icteroides . .	+	—	—	+	+	+	A	+	+	+	A	+	—	—
B. psittacosis . .	+	—	—	+	+	+	+	+	+	+	+	+	—	—
B. of epidemic jaundice . .	+	—	—	+	+	+	+	+	+	A	—	—	—	—
B. of hog-cholera .	+	—	—	+	+	+	A	A	+	+	A	+	—	—
B. paracolon (LeSage)	+	—	—	+	—	+	+	+	+	+	+	—	—	—
B. paratyphoid (Schottmüller, A)	+	—	—	+	+	+	+	+	+	+	+	+	—	—
B. paratyphoid (Schottmüller, B)	+	—	—	+	+	+	+	+	+	+	+	+	—	—
B. "L" of Hume .	+	—	—	+	+	+	+	+	+	+	+	+	—	—
B. pyogenes fœtidus	A	A	A	A	A	A	A	A	A	A	A	A	—	—
B. typhosus . .	A	—	—	A	A	A	—	A	A	A	—	A	—	—
B. typhosus simulans	A	—	—	A	A	A	A	A	A	—	—	A	—	—
B. dysenteriæ. .	A	—	—	A	A	A	—	A	—	—	—	—	—	—

+ signifies acid and gas production. A signifies acid production only.

Much confusion has existed in regard to the lactose-fermenting bacteria of fæces and dirty water; a glance at the table above shows that the differentiating points have reference to the fermentation or otherwise of sucrose and dulcite, and the presence or absence of the "Kalilauge-roth-reaktion." The *B. acidi lactici* is representative of a group which split neither sucrose nor dulcite; *B. neapolitanus* or *B. pneumoniæ* may be taken as typical of those which ferment both; the *B. coli communis* represents those which split dulcite but not sucrose; while *B. lactis aerogenes*, *B. capsulatus*, and *B. cloacæ* all ferment cane-sugar but not dulcite; it is further characteristic of this last group that they give the Voges-Proskauer reaction. Harden

has, further, shown that the first three groups all produce alcohol and acetic acid from glucose in approximately equal molecular proportions, while the fourth group produce more than 2·5 molecular proportions of alcohol to 1 of acetic acid.*

Methods for isolating B. typhosus from Water.—The difficulties in the way of isolating the enteric micro-organism from an infected water are very great, mainly because it is likely to be present in relatively small numbers. The following methods have been used or suggested:—

(1) *Concentration.*—By passing the sample through a sterile candle-filter under pressure, all the organisms contained in a considerable volume can, in theory, be collected on the filter and then transferred by brushing to a few cubic centimetres of sterile water; from this concentrated water the subsequent cultures are made. An alternative method is to evaporate the water under reduced pressure.† The more or less anaerobic conditions prevailing and the high temperature favour the development of the typhoid bacillus, and are inhibitory to many water organisms.

(2) *Enrichment.*—The principle underlying all methods of this kind is the employment of a fluid medium which will allow the *B. typhosus* to multiply and at the same time prevent, or at least inhibit, the growth of other micro-organisms, more particularly *B. coli.*

Parietti suggested a solution containing 5 grammes of carbolic acid and 4 grammes of hydrochloric acid in 100 c.c. of water; of this solution 0·1, 0·2, and 0·3 c.c. are added to a series of 10 c.c. broth tubes, so that the tubes contain 0·05, 0·10, and 0·15 per cent. of carbolic acid. One c.c. of the water is then added to each of the tubes, which are incubated at 37° C. for twenty-four hours. All the tubes which show any growth are then plated out in gelatin; the colonies which develop are examined under the microscope, and those resembling *B. typhosus* are subcultured in various media. Tiemann-Gärtner found that the *B. typhosus* often did not grow in broth containing 0·10 and 0·15 per cent. of carbolic acid, and Lösener obtained similar results. Vincent recommends the addition of five drops of a 5 per cent. solution of carbolic acid to the broth tubes, which are then incubated at 42° C. Ravitsch-Stcherva added 0·1 per 1000 of α-naphthol to the nutrient medium. Lösener did not obtain satisfactory results with this method. The surface of the *B. typhosus* was green in colour, granular, raised in the centre, and not easily recognised.

Recently, Hoffmann and Ficker ‡ have utilised the inhibitory influence of caffein on *B. coli* and other organisms without interfering much with the growth of *B. typhosus.* They convert the water sample itself into a nutrient medium by adding 1 per cent. of nutrose, 0·5 per cent. of caffein, and 0·001 per cent. of crystal violet. The mixture is incubated at 37° C. for not more than twelve hours. At the end of this time enteric bacilli, if present, will be sufficiently numerous to be isolated on plates without difficulty, whereas colon bacilli will be almost restrained in their growth. We have worked with this method and found it successful, but we have also had failures; the drawback to it seems to be that the action of caffein is by no means uniform.

(3) *Agglutination.*—Windelbandt first suggested the use of anti-enteric serum for the isolation of the specific bacillus from water. He added 1 c.c. of the infected water to a series of broth tubes, and incubated at 37° C.

* Harden: "Fæcal Bacteria; Chemical Action on Glucose," *Journal of Hygiene,* vol. v. p. 488.

† Wilson: "New Method for Isolating the Bacillus Typhosus from Infected Water," *Brit. Med. Journal,* 1907, vol. i. p. 1176.

‡ Hoffmann and Ficker: *Hygienische Rundschau,* 1904, Bd. xiv. p. 1.

for four days. To those showing a diffused turbidity, a few drops of an active anti-enteric serum were added. If clumps formed, they were separated out by centrifugalisation. On emulsifying the deposit in sterile water, plates were prepared from the emulsion. Schepilewski * and Altschüller † both made modifications in the method, but report favourably of it. Our own experience of this procedure is not favourable, as, unless the bacilli were added to the test-water in considerable numbers, negative results only were obtained.

(4) *Chemical precipitation*, or the formation in the suspected water of an inert precipitate which entangles and carries down the bacteria, is the basis of three well-known methods, namely, the Vallet-Schüder, the Ficker, and the Willson.

In the Vallet-Schüder method, 20 c.c. of a 7·75 per cent. solution of sodium hyposulphite and 20 c.c. of a 10 per cent. solution of lead nitrate are added to two litres of the water to be examined. After the precipitate has settled, the volume of water is centrifugalised. The precipitate is separated and dissolved in a saturated solution of the hyposulphite. From this solution plates of suitable media are inoculated. According to Schüder, a water containing 1,400,000 organisms per c.c. had, after treatment by this method, only 700 per c.c. left.‡

In Ficker's method, the precipitant is ferrous sulphate. Two litres of the water sample are rendered faintly alkaline with soda and 7 c.c. of a 10 per cent. solution of ferrous sulphate added. After precipitation and centrifugalising, the precipitate is dissolved in a 25 per cent. solution of neutral potassium tartrate. Ficker claims that 98 per cent. of the organisms contained in the water are carried down in the precipitate, which has no germicidal action on the enteric bacillus.§ We have tried both these methods, and succeeded in recovering the *B. typhosus* from eighty litres of water by the first and from fifty litres by the second, after infection in both cases with 0·1 c.c. of fresh enteric fæces.

The alum precipitation method is one suggested by Willson ‖ in which he added the precipitant in the proportion of 0·5 gramme to the litre. After centrifugalising, the precipitate is spread over the surface of one or more Drigalski-Conradi plates; these were incubated at 42° C. for forty-eight hours. We have had no opportunity of testing this particular method, but judging by our experience with both the other chemical precipitants, have no doubt but that it is capable of demonstrating the enteric bacillus in considerable dilutions. The author's own experiments certainly indicate it to be practicable.

It may be asked which of these alternative methods is the best for the routine examination of water suspected of infection by the enteric micro-organism? Where a considerable volume of water has to be searched, and we certainly think it is likely to be a waste of time if less than two litres are used, the conversion of the water itself into a nutrient medium is the best method to adopt. Of all enrichment methods, that of Hoffmann and Ficker has been the most successful, but it must be remembered that caffein varies in its action; of other methods, we confess to liking that of Schüder, but Willson's alum process is perhaps simpler. In competent hands, it is probable that they are all equally reliable, but whatever process is used for the preliminary treatment of the water under examination, for the final

* Schepilewski: *Centr. f. Bakter. Originale*, xxxiii. No. 5, 1903.
† Altschüller: *Centr. f. Bakter. Originale*, xxxiii. No. 9, 1903.
‡ Schüder: *Zeitsch. f. Hygiene*, Bd. xlii. 2, p. 317.
§ Ficker: *Hygienische Rundschau*, 1904, Bd. xiv. No. 1, p. 7.
‖ Willson: "Isolation of B. Typhosus from Water," *Journal of Hygiene*, vol. v. p. 429.

isolation of the bacillus special solid media must be employed. The basis of nearly all these differential media is enrichments coupled with the use of certain substances which, by means of colour reactions, facilitate the separation of organisms. Thus, if lactose alone be added to litmus agar, only the lactose fractors will produce acid and show pink colonies ; if dulcite alone, only the dulcite fermenters; if sorbite alone, only the sorbite fermenters, and so on. Examples of the first, or simple enrichment, method are Elsner's acid potato gelatin with 1 per cent. of iodide of potassium, also Uffelmann's carbolic gelatin, on both of which saprophytes were said to grow with difficulty, while the *B. typhosus* did so readily. Despite some successes with both these media, gelatin does not commend itself in the search for the enteric organism, and during recent years special agar media have been devised, the best of which are :—(1) Endo's medium, which is an alkaline lactose agar containing fuchsin, but rendered colourless by the addition of sodium sulphite ; (2) bile-salt lactose neutral red agar ; (3) alkaline glucose agar ; (4) neutral lactose agar ; and (5) Drigalski-Conradi agar, which is really nutrose-lactose-litmus agar with a trace of crystal violet. Each one of these media has its advocates, but in no sense can any one of them be regarded as specific for *B. typhosus ;* we have worked with them all and, for ordinary routine water work, prefer the last two in the order named. When working with them, the medium is melted and plates are poured in the ordinary way and allowed to set. Before use, the plates should be dried for a few hours in the warm incubator. They are then inoculated by spreading or streaking the suspected fluid over the surface and incubated at 42° C. On these media, the growth of many saprophytic organisms is prevented or restrained, but *B. coli*, typhoid, and allied forms grow readily and produce characteristic colonies. After twenty-four hours, *B. coli* colonies are well developed, glistening white by reflected light, bright red by transmitted light, whereas *B. typhosus* colonies are smaller, more delicate in appearance, and bluish white in colour, never producing any change in the medium. The various "intermediates," and some other strains which have little or no action on lactose, are often difficult to distinguish from typhoid colonies until they have grown for at least forty-eight hours at 42° C., when a slight redness in the centre of the colony may be seen, though the growing margin remains blue and the medium unchanged. The *B. fluorescens non-liquefaciens* and *B. pyocyaneus* colonies resemble typhoid, but the extraordinary motility of these bacilli in a hanging-drop preparation generally gives a clue, and a few subcultures soon settle the diagnosis. The streptococci are distinguished readily by their very thin, delicate colonies, usually faintly red in colour. Some vibrio and spirillum forms appear as bluish colonies, but a very cursory examination will prevent their being confused with enteric bacilli.

The Spirillum Choleræ is an important organism to those engaged in examining water-supplies in tropical countries. It is a small curved micro-organism resembling a comma ; usually only one curve is seen, but sometimes two spirilla are attached ends on, and an **S**-shape produced. It is very motile, having a single flagellum at one end. It does not form spores, but degraded or involution forms are not uncommon, when it appears short and thick like a large coccus. It is markedly aerobic, and grows best at 37° C. The colonies on gelatin plates, in twenty-four to forty-eight hours, appear as minute white points, which under a low power show an irregular margin. Later, liquefaction of the gelatin occurs. If grown as a gelatin stab, well-marked liquefaction is seen on the third day as a funnel-like depression. The growth on an agar slope is not characteristic,

but on agar plates the surface colonies appear under a low power as very transparent, brownish yellow, circular discs. In broth, there is diffuse turbidity with a thin pellicle on the surface. Milk remains unchanged; the growth on potato is not characteristic. Indol and nitrite production is rapid and marked in peptone and salt solution, requiring only the addition of a few drops of pure sulphuric acid to show the so-called "cholera-red" reaction. There is no production of gas in the sugar media, but acid is formed in glucose. If a cholera serum is available, agglutination of this spirillum is marked in dilutions from 1 in 10 to 1 in 120.

The difficulties of diagnosing the true cholera spirilla in water are often great, and mainly owing to the fact that large numbers of other spirilla may be present which are not necessarily pathogenic. The various species may be divided into two classes, A and B.

Class A includes the following organisms, which are easily distinguished from the true cholera spirillum of Koch. The *spirillum of Finkler and Prior*, found in water by Gruber and his pupils. It is a thicker spirillum than Koch's, and liquefies gelatin more rapidly. It produces indol but no nitrites, so that the "cholera-red" test is not usually given; occasionally traces of nitrites may be formed, and then the reaction will be given slowly and imperfectly. *Renow's spirillum* was isolated from well-water. It is three times as long and twice as thick as Koch's spirillum. *Vibrio aquatilis*, found by Günther in Spree water. This organism exactly resembles the spirillum of Koch in microscopical characters, but its young colonies have a perfectly smooth rim, and are thus easily distinguished from the colonies of Koch's spirillum. It does not give the "cholera-red" reaction, and refuses to grow on potato either at 22° C. or 37° C. *Russell's spirillum* was isolated from the Gulf of Naples. It does not grow at 37° C. *Kiessling's spirillum* was isolated from the water of the sand-washings at Altona. It appears to be identical with Günther's *Vibrio aquatilis*.

Weibel has described several spirilla which he isolated from sewer mud. The *Vibrio saprophiles* α and γ are easily distinguished by the appearances of the colonies, which are smooth-rimmed and do not liquefy gelatin. The *Vibrios aureus* and *flavus* are also distinguished by the appearance of the colonies, which are smooth-rimmed, acquire a yellow colour, and do not liquefy gelatin. The *Spirillum rubrum*, described by Esmarch, was also isolated from water by Adametz. It is easily distinguished by its colonies on gelatin, which very slowly acquire a wine-red colour and do not liquefy gelatin. The *Spirillum volutans*, *S. serpens*, and *S. undula*, found in stagnant waters, are all much larger than Koch's spirillum, and generally form many spiral turns. The *Bacillus choleroides* α and β, isolated by Bujwid from water, very closely resemble Koch's spirillum. They are said to liquefy gelatin more rapidly than Koch's organism, and the colonies possess a smooth margin.

Class B.—The organisms included in this class give rise to great difficulties in diagnosis. They are as follows:—

The *Vibrio Berolinensis*, isolated by Neisser from Berlin sewage, differs from Koch's spirillum in that it liquefies gelatin very slowly. The colonies appear as smooth expansions which do not sink in gelatin. It does not give Pfeiffer's reaction. The *Vibrio Danubicus*, isolated by Heider from canal-water, is very like the true cholera spirillum; but it does not give Pfeiffer's reaction, the colonies are different, and it liquefies gelatin rapidly. It is also very pathogenic to guinea-pigs. The *Vibrio of Massowah*, isolated by Pasquale, was at one time regarded as the true cholera organism. It does not give Pfeiffer's reaction, possesses four flagella, and is very pathogenic to pigeons.

The *Vibrio Gindha*, discovered by Pasquale in well-water, does not give the "cholera-red" and specific immunity reactions.

Sanarelli isolated four vibrios from the river Seine, which gave the "cholera-red" reaction, and were pathogenic to guinea-pigs. This observer believes there may be many vibrios capable of producing symptoms of cholera. Lastly, Dunbar has found many spirilla in the Hamburg pipe-water, and in water from the Elbe and Oder, which cannot be easily distinguished from true cholera spirilla. Some of these spirilla showed phosphorescence in the dark, which is never observed with true cholera spirilla. However, the phosphorescence was not found absolutely constant; so it is still doubtful whether these spirilla were really true cholera organisms. In this connection it is noteworthy that in our own experience, when examining waters in India, during periods of cholera epidemicity, the excessive prevalence of phosphorescent spirilla has been observed. Although, culturally, they were difficult to distinguish from the spirillum of Koch, precise evidence was lacking to show that these phosphorescent spirilla were pathogenic or directly associated with the causation of cholera.

For the isolation of the cholera spirillum from a water sample, the following is the simplest and most practical method. It is based on the fact that the optimum medium for the growth of the organism is one containing 1 per cent. of peptone and 0·5 per cent. of salt, and really consists in converting as much of the suspected water as possible into such a solution, incubating at 37° C. for a few hours, and if the spirilla are present, isolating them from it. The technique suggested is to make a strong or stock solution containing 10 per cent. of peptone and 5 per cent. salt; 10 c.c. of this solution are added to 90 c.c. of the water placed in a sterile flask, which is then incubated at 37° C. After twelve to twenty-four hours the contents of the flask become turbid if cholera spirilla are present. Loopfuls must then be removed from the surface of the fluid in the flask, and plated out in gelatin, or rubbed over the surface of agar solidified in Petri-dishes. If pure cultures of spirilla are then obtained, the colonies must be planted out in the following media :—

(1) Peptone and Salt Solution.—After twenty-four hours' incubation at 37° C., the tube will become turbid, and on the addition of pure sulphuric acid the cholera-red reaction will be obtained.

(2) Gelatin Plates.—The characteristic colonies with an *irregular* margin will appear.

(3) Gelatin Slope.—The typical funnel-shaped liquefaction will be obtained.

(4) Agar Slope.—The growth which appears in twenty-four hours at 37° C. must show with anti-cholera serum both the agglutination test and Pfeiffer's reaction.

(5) A portion of the colony should be examined for the typical microscopical appearances.

Metchnikoff recommended the following method:—A series of Vivien's flasks are prepared; into each flask the following solution is poured, *i.e.*, water 50 c.c., peptone 2 grammes, salt 2 grammes, gelatin 4 grammes, and a solution of soda sufficient to give slight alkalinity. The flasks are sterilised in the autoclave, and then 150 c.c. of the suspected water are added to each of them. The flask and contents are incubated at 37° C.; if a film appears on the surface after eight to twelve hours, loopfuls are removed and treated as above described. If a spirillum conforms to all the tests it is probably the true cholera vibrio, but it must be remembered that a certain number of spirilla, although agglutinating to some extent with cholera serum, are differentiated sharply from the cholera vibrios by the fact that they are multiciliated and hæmolytic.*

Streptococci in Water.—The hygienic significance to be attached to the presence of these micro-organisms in water has been much debated.

* Ruffer: "On the Bacteriological Diagnosis of Cholera," *Brit. Med. Journal*, 1907, vol. i. p. 735.

They, undoubtedly, are present in large numbers in all sewage, and can be found, too, if searched for, in the majority of polluted waters. Owing to their minuteness, the delicacy of their colonies, and the not infrequently large volumes of water which must be concentrated, by either filtration or precipitation methods, for their detection, the routine search for these micro-organisms is the exception rather than the rule in the bacterial examination of water samples. We are disposed to think that this neglect of noting the presence or absence of streptococci is unwise, as although the presence of streptococci alone cannot be considered as indicating necessarily a dangerous contamination, still, in view of the fact that these organisms tend to disappear rapidly in dilutions of old sewage, their presence in a water-supply indicates a recent contamination, but unless they are accompanied by the presence of *B. coli*, this contamination is not necessarily dangerous. On the other hand, their absence does not of itself imply purity and safety; while their presence, at all events in any number, even in the absence of *B. coli* and other fæcal organisms, is evidence highly suggestive of doubt as to the fitness of a given sample for domestic use, and should be a signal for a more critical inquiry into the circumstances. For the isolation of streptococci from water, the concentration of not less than 500 c.c. to 10 c.c. by filtration through a sterile bougie, and subsequent plating in gelatin or on agar, probably constitutes the most satisfactory technique.

The streptococci are small or medium-sized cocci arranged in chains of varying length. They stain with the basic dyes and also by Gram's method; none appear to be acid fast. The greater number of strains which we have isolated from sewage and sewage-polluted waters do not liquefy gelatin, but a few varieties do so. On gelatin plates, the surface colonies are granular, circular, and extremely small, with a clear sharp edge, but a few present streaming projections from the margin. In broth, the resulting growth is generally diffuse, but sometimes confined to definite points on the sides of the glass. Milk is variably affected; similarly, indol is variably produced in peptone and salt solution. On potato and on agar, the growths are not characteristic; while in the various carbohydrates, glucosides and polyatomic alcohols there is practically never any gas formation, but variable acid production. It has been the absence of satisfactory criteria for judging the specific characters of the various streptococci which has hitherto complicated the problem of the identity or non-identity of the types found. Thanks, however, to some recent work by M. H. Gordon * and Andrewes and Horder,† we are in a position to make at least a provisional classification of this group. The basis of the classification is how different streptococci behave when subcultured in nine different media, namely, the ability to reduce neutral red under anaerobic conditions, the clotting of milk, and the production of acid in the two di-saccharides sucrose and lactose, the tri-saccharide raffinose, the poly-saccharide inulin, the two glucosides salicin and coniferin, and the alcohol-mannite. In the case of the last seven tests, the method consists in preparing a sugar-free broth, and adding to it 1 per cent. of the test substance, together with some litmus.

Judging them by their general cultural behaviour in the above nine test media, Andrewes and Horder have suggested the following provisional classification of the streptococci into seven groups.

Group A is composed mainly of saprophytic cocci derived from the intes-

* Gordon: *Report Med. Off. Local Gov. Board*, 1903 4, vol. xxxiii. p. 388; also *Lancet*, 1905, vol. ii. p. 1400.

† Andrewes and Horder: "A Study of the Streptococci Pathogenic to Man." *Lancet*, 1906, vol. ii. pp. 708, 775, and 852.

tines of the herbivora, whose type is the *streptococcus equinus* so common in horse-dung. The positive test reactions of this group are fermentation of sucrose, salicin and coniferin, coupled with inability to grow on gelatin at 20° C. and non-pathogenicity. No one of the reactions is constant, but the limitations of the reactions to sucrose and the two glucosides is constant.

Group B is essentially saprophytic, occurring chiefly in human saliva and fæces. It may be defined as a short-chained form, growing well on gelatin at 20° C., acidifying but not clotting milk, reducing neutral red, and fermenting sucrose and lactose with or without the glucosides. This saprophytic type has been named provisionally *streptococcus mitis*, and is of chief interest as the probable form from which the virulent streptococcus pyogenes has arisen.

Group C has for its type the classic *streptococcus pyogenes*. Its characters are as follows :—a long-chained form usually growing in woolly masses at the bottom of a clear broth. It grows well on gelatin at 20° C. It is actively hæmolytic, acidifies milk but does not clot it, neither does it reduce neutral red. The usual positive reactions with Gordon's tests are sucrose, lactose and salicin, but a variant, lacking the salicin reaction, is quite common.

Group D is represented by the *streptococcus salivarius*, or the common form present in the mouth and occasionally in the intestine. The typical characters of this streptococcus are as follows :—a short-chained form which usually renders broth uniformly turbid, though sometimes the broth is clear with a deposit of short chains. It does not usually grow well on gelatin at 20° C. ; it clots milk, reduces neutral red, and acidifies sucrose, lactose and raffinose. Streptococcus salivarius is for the most part non-pathogenic, but there is much to suggest that it is related to the pneumococci, which may prove to be a pathogenic offshoot from it.

Group E contains the pathogenic long-chained forms of the streptococcus salivarius, which seem to have a special connection with inflammation of the fauces and with scarlet fever. It is common in other sore throats, and also in the normal alimentary canal ; the term *streptococcus anginosus* has been suggested for it. It is a long-chained form, producing in broth a flocculent deposit like that of streptococcus pyogenes, but differs from that by not growing on gelatin at 20° C., habitually clots milk and reduces neutral red, also acidifies sucrose, lactose, and not infrequently raffinose. Other variants ferment the glucosides, and in rare cases inulin.

Group F embraces the streptococci so characteristic of the human intestine, and under the term *streptococcus fæcalis* is of paramount interest to the water examiner. This streptococcus is mostly short-chained, rendering broth uniformly turbid, grows readily on gelatin at 20° C., in a few cases liquefies this medium, ferments sucrose, lactose, salicin, coniferin and mannite, clots milk and reduces neutral red. Of course there are variants, but the mannite reaction is so strikingly constant that it seems justifiable to assert that it is characteristic of a large number of intestinal as opposed to salivary streptococci. A noticeable feature of this streptococcus is its ability to resist prolonged dessication.

Group G contains the *pneumococci*. Their distinguishing mark is the possession of a capsule when growing in the animal body and in certain culture media. On the ordinary media this capsule is not apparent, and the cocci form frequently long chains. The type reactions are an inability to grow on gelatin at 20° C., acidification of sucrose, lactose and raffinose, clotting of milk and occasionally a reaction in inulin.

The following table presents the general reactions of the various strepto-

cocci on the basis of the foregoing classification, which at best is arbitrary. Needless to say, there are numerous variants by suppression or addition, which represent the imperceptible gradations by which each group shades off into another. In spite of its crudity, we consider this classification to be a marked advance in our knowledge of these micro-organisms, and by means of it we can readily place a streptococcus and surmise its source and probable virulence. Intelligently used, this table and the classification

Group.	Type.	Grows in Gelatin at 20° C.	Clots Milk.	Reduces Neutral Red.	Acidifies Sucrose.	Acidifies Lactose.	Acidifies Raffinose.	Acidifies Inulin.	Acidifies Salicin.	Acidifies Coniferin.	Acidifies Mannite.	Is Pathogenic.
A	S. equinus . . .	.	.	.	+	.	.	.	+	+	.	.
B	S. mitis . . .	+	.	+	+	+	.	.	?	?	.	.
C	S. pyogenes . . .	+	.	.	+	+	.	.	+	.	.	+
D	S. salivarius . . .	.	+	+	+	+	+	.	.	.	.	.
E	S. anginosus . . .	.	+	+	+	+	?	.	?	?	.	+
F	S. fæcalis . . .	+	+	+	+	+	.	.	+	+	+	+
G	Pneumococci . . .	.	+	.	+	+	+	?	.	.	.	+

on which it is based cannot fail to be of value to the water examiner, and every streptococcus isolated needs to be subcultured in the carbohydrates, glucosides and the alcohol mannite as much as any bacillus suggestive of the colon-enteric-dysentery series.

The B. Enteritidis Sporogenes.—Since Klein first described this micro-organism as being found in all sewages, dirty waters, horse-dung, and earth from manured fields, its presence in or absence from water samples has been deemed a matter of importance. It is an obligatory anaerobic bacillus of considerable size, of variable mobility, staining by Gram's method, and producing under certain conditions oval spores situated in the middle of the rods. On solidified serum it grows well at 37° C., the serum being liquefied gradually, and spores forming about the third day. It grows well also in glucose agar, splitting and tearing up the medium by a copious formation of gas-bubbles. It grows in much the same way in glucose gelatin, slowly liquefying this medium. On the surface of an agar slope, the colonies are grey, flat expansions, having no crenations, and the individual bacilli producing no spores. When grown in milk, there is a rapid separation of acid-whey and flocculi of casein, much gas-formation with a distinct smell of butyric acid. No spores are produced in milk. The separated whey swarms with bacilli, and is actively virulent if injected into rodents.

The hygienic significance to be attached to this micro-organism has been much debated. Our experience indicates it to be present invariably in horse-dung, street-sweepings, manure from fields, and in most sewages. Its detection in undoubtedly dirty and sewage-polluted waters is not constant, so much so that we are disposed to doubt whether its importance, as an indicator of sewage in water samples, has not been overrated. Many of the discrepancies as to this micro-organism appear to be due to the fact that there are two other organisms in constant association with filth and decomposing animal matter which present marked resemblances to the *B. enteritidis sporogenes* of Klein, and with which it seems to have been confused; these are the *B. butyricus* of Botkin, and the *B. cadaveris sporogenes*. The accompanying table (given by Klein) shows the essential difference between these three anaerobic bacilli.

Experience indicates that, unless care is exercised, it is easy to confuse these micro-organisms one with the other, especially if too much reliance is placed upon the milk reaction. Unless an organism gives all the reactions, particularly that of pathogenicity, it should not be called the *B. enteritidis sporogenes*, but for practical purposes of water-analysis it appears sufficient to identify any one of these three anaerobic bacilli, as the presence of any one of them is significant of pollution. As these spore-bearing organisms occur rarely in large numbers even in dirty waters, the bacterial contents of a fairly large volume of the water sample should be used for their detection. This should be about 500 c.c., which must be filtered through a sterile bougie, the organisms arrested on the surface of the filter being then brushed by means of a sterile brush into 10 c.c. of sterile water. Varying proportions of this must be then transferred to tubes of recently boiled sterile milk, the temperature of which at time of inoculation should not exceed 80° C., and then grown anaerobically. The portions may be conveniently distributed into three milk-tubes, namely, 6 c.c. into one, and the remaining 4 c.c. equally into two others. Some melted vaseline is then poured over the surface of the milk, in order to exclude air by formation of a covering some half-inch in depth. The milk tubes are then placed in a water-bath at 80° C. for twenty minutes, cooled until the vaseline is well set, and finally incubated

B. enteritidis sporogenes.	B. butyricus.	B. cadaveris sporogenes.
Broad cylindrical rods, staining with Gram; some motile.	Same as *B. enteritidis sporogenes.*	Cylindrical, thin, thread-like rods; very motile; staining with Gram.
Oval spores situated in the middle of the rods.	Same as *B. enteritidis sporogenes.*	Oval spores situated at the end of the rods, drum-stick-like.
Grows well on gelatin which liquefies slowly.	Does not liquefy gelatin, but grows as a mass of convoluted threads.	Liquefies gelatin rapidly, emitting a putrid odour. Free spore formation.
As a stab in gelatin, spherical colonies appear with no filamentous projections. Slow liquefaction.	As a stab in gelatin, spherical colonies with horizontal filamentous projections. No liquefaction.	As a stab in gelatin, rapid liquefaction with putrid odour.
On an agar surface gives circular flat colonies. No spore formation.	On an agar surface, grey flat colonies with crenated edge. No spores.	On an agar surface, thready branched colonies, rapidly forming spores.
As a stab in agar, little tendency to form lateral branching. Much gas. No spores.	As a stab in agar, characteristic bundles of threads project laterally in the depth. Much gas, no spores.	As a stab in agar, free growth of threads along the stab. Much gas. Rapid spore formation.
In milk there is a rapid separation of acid whey and flocculi of casein. Much gas, no spores, but marked smell of butyric acid.	Same as *B. enteritidis sporogenes.*	In milk, much gas formed, also rapid spore formation; the milk is decomposed slowly.
On serum, free growth with slow liquefaction. Spores are formed.	On serum grows well, very slow softening.	On serum, rapid liquefaction, with putrid odour and free spore formation.
Injected into rodents. Very virulent.	Not pathogenic to rodents.	Not pathogenic to rodents.

at 37° C., for three days. If any of these anaerobic bacilli are present, the typical changes in the milk-tubes will be produced. If no result is produced in any of the three tubes inoculated, the water sample may be said to contain less than one spore per 500 c.c.; if the typical change occur in the one which received the 6 c.c. of filter brushing, but not in the other two, the water is assumed to contain less than one spore per 100 c.c., but one or more in 300

c.c. If the typical change occurs in one or both the other tubes, there is probably one or more spores in each 100 c.c. of the sample. If the milk reaction is so atypical as to raise doubts as to whether the organism present is really the *B. enteritidis sporogenes*, but rather one of its allies, the point can only be settled by careful subculture on the lines indicated. We have never detected any of these anaerobic micro-organisms in a water sample, without finding concurrent evidence of the *B. coli* and other fæcal forms.

THE INTERPRETATION OF THE RESULTS OF A WATER ANALYSIS.

This often offers undoubted difficulties, especially to the student and others depending exclusively upon the results of a chemical analysis. The reasons for this are twofold:—(1) At best the indications given by the chemical examination are only relative, as the results obtained cannot be interpreted correctly except by reference to local standards ; (2) between an undoubtedly good water and an undoubtedly dirty water there is a considerable range of waters whose chemical analytical features are very ambiguous. There is no general standard which can be fixed for all waters ; the source and its immediate surroundings must be known before a reliable opinion as to the quality of the water can be given. What we need is a carefully constructed series of water standards for individual areas or districts. These standards should relate, not only to chemical constituents, but to bacterial contents. These standards would be of great value in respect of surface waters, where any serious departure from the average would at once suggest cause for critical inquiry as to the why and wherefore. In the absence, then, of district standards or averages, what can be done ? We can depend only upon the following procedures, which we place in their order of value : (1) A careful local inspection for any source of possible pollution ; (2) a bacteriological examination made as soon as possible after collection of the sample ; (3) a chemical analysis. It is rare for a sample of water to yield doubtful results under either the second or third heads when the report under the first has been carefully obtained and found to be free from suggestive features. We therefore attach the greatest importance to this matter of local inspection, feeling sure that if carefully and intelligently carried out, it affords information of the greatest value. In the preceding pages, an attempt has been made to show on what lines a bacterial examination of a water sample should be conducted, and the probable results likely to be obtained in the case of clean and dirty waters respectively. We are indisposed to lay down numerical standards as to the presence of individual bacterial forms in water ; such, we know, have been formulated, but, in our opinion, they are apt to be used in too routine a manner. Each individual water sample must be judged on its merits with due regard to all the facts. While it is difficult to conceive a properly constructed deep well, and apparently remote from sewage pollution, yielding a water containing any fæcal micro-organisms, no matter how large a volume was carefully examined, it involves less imagination to account for the presence of such forms in comparatively small amounts of surface water, such as are obtained from lakes, ponds, rivers, or shallow wells imperfectly protected.

As to the chemical results, we would say no more than that the evidence of present or recent animal pollution is especially suggested by high chlorine and oxidised nitrogen in association with marked free and albuminoid ammonia ; that of past or remote animal pollution by high chlorine and

oxidised nitrogen (not explicable as derived from geological strata) with generally little free and albuminoid ammonia. If the fouling is chiefly of vegetable origin, we may expect to find high figures for albuminoid ammonia and oxygen absorbed in association with low figures of chlorine and oxidised salts of nitrogen.

Deep wells often show a large amount of free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would point to probable sewage pollution, or at least to the presence of urine.

The presence of a considerable amount of albuminoid ammonia, with little free ammonia and chlorides, is generally indicative of vegetable organic matter, often peaty. If the chlorine be high, that is, in excess of the average of the district, it may be inferred that the material which yields the ammonia is in great part of animal origin.

The real significance of the albuminoid ammonia has been much discussed, but the results obtained are sufficiently uniform to give us a convenient measure of purity, provided we are careful not to draw the line too close. All the nitrogen of the organic matter is certainly not obtained by this method, but this is immaterial so long as the proportion is fairly maintained. The results correspond to a certain extent with the *organic nitrogen* of Frankland, and the process is much more feasible for medical officers generally. Practically 0·615 part of albuminoid ammonia per 100,000 equals 1 part of Frankland's organic nitrogen per 100,000; and double the nitrogen from the albuminoid ammonia equals the organic nitrogen as determined by Kjeldahl's process.

Beyond this general statement we are not prepared to dogmatise; it may be asked, what constitutes a high figure in respect of these various constituents? The line of demarcation in each case may be taken for practical purposes at the figures already given when explaining the respective analytical procedures advocated. As typical of actual analytical results, a few examples of waters from different sources, with expressions of opinion upon them, are given in the following table, expressed in parts per 100,000:—

Source and Circumstances.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed.	Nitric and Nitrous Nitrogen.	Nitrites.	Bacteriological Results.	Opinion.
1. Surface water from moor, well policed.	1·0	0·003	0·012	0·290	0·16	*Nil.*	No sewage forms found.	Safe.
2. Shallow well, apparently well protected.	2·2	0·011	0·009	0·200	0·002	*Nil.*	No sewage forms found.	Doubtful; unsatisfactory.
3. Deep well, well protected.	2·8	0·010	0·004	0·060	0·030	*Nil.*	No sewage forms found.	Safe.
4. Deep well, coping, cover, and steining defective.	29·0	0·055	0·002	0·110	0·110	*Nil.*	Sewage organisms present.	Polluted; unsafe.
5. Deep well in farmyard.	19·0	0·018	0·004	0·110	0·390	Traces.	Sewage forms found.	Unsafe; polluted.
6. Shallow well in farmyard.	1·0	*Nil.*	0·003	0·040	0·800	*Nil.*	No sewage forms found.	Safe.
7. Deep well, protected.	22·0	0·011	0·004	0·060	0·090	*Nil.*	No sewage forms found.	Safe.
8. Spring in a copse, no protection.	1·6	0·020	0·001	0·015	1·100	*Nil.*	No sewage forms found.	Unsafe.
9. Spring, close to a ditch liable to overflow.	4·0	*Nil.*	0·006	0·200	1·700	*Nil.*	Sewage organisms present.	Unsafe.
10. Spring in meadow, not well guarded, ditch near.	3·9	0·008	0·030	0·180	0·200	*Nil.*	Sewage organisms found.	Unsafe; polluted.
11. Spring, well protected.	3·0	0·009	0·006	0·122	0·600	*Nil.*	No sewage forms found.	Safe.
12. Shallow well, risk of sewage from blocked drain suspected.	12·5	0·005	0·006	0·150	1·500	Traces.	*B. coli* found.	Unsafe.

LAW RELATING TO WATER-SUPPLY.

In England and Wales.—Owing to the privileges which, from time to time, have been granted to companies and other corporate bodies, Sanitary Authorities are under certain restrictions as to their supplying water. Where a water company has Parliamentary powers to supply water over any given area, the Sanitary Authority must give notice to the company stating the purposes for which and extent to which it requires water; and if the company are able and willing to supply sufficient and proper water for the purposes of the local authority, this latter body may not construct any waterworks within that area (Public Health Act, 1875, section 52). Moreover, section 332 of the Act provides that where the supply of water must be taken from a running stream, the Sanitary Authority, before abstracting water from such stream, river, or source, must obtain the consent in writing of any person or persons who have prior claims upon those streams.

When not hampered by either of the foregoing restrictions, any Sanitary Authority may construct works for supplying any part of their district with water, or may take on lease, or hire, or purchase works (with the sanction of the Local Government Board), or contract for the supply (section 51). When a Sanitary Authority supply water within their district, they have the same powers and are under the same restrictions for carrying their mains within and without their district as they have and are subject to in respect of their sewers (section 54). The water supplied must be pure and wholesome, and under sufficient pressure as will carry the same to the top storey of the highest dwelling-house in the district supplied. There is, however, no obligation to provide a constant supply under pressure (section 55). The Sanitary Authority have power to charge water-rates and rents in respect of premises to which they supply water, while all public cisterns, pumps, wells, &c., used for the gratuitous supply of water to the inhabitants of a district, vest in and are under the control of such authority (sections 56 and 64).

The same Act, section 62, gives any Sanitary Authority power to require houses which are without a proper water-supply to be so supplied, if it can be furnished at a cost not exceeding the water-rate authorised by any local Act, or twopence a week, or such other cost as the Local Government Board may, upon application, determine to be reasonable. In order to guard against the pollution of sources of water-supply, the Sanitary Authority have power to proceed against offenders (sections 68, 69). If the water of any well or cistern is deemed to be injurious to health, a justice's order may be obtained for its being permanently or temporarily closed, or the water to be used for certain purposes only, and for the payment of any necessary analysis of the sample at the cost of the Sanitary Authority (section 70).

The general provisions of the Public Health Act, 1875, in respect of water-supply may be briefly summarised by saying that it is the duty of the Sanitary Authority to provide their district with water, where danger exists to the health of the inhabitants from either the unwholesomeness or the insufficiency of the existing supply, and a proper supply can be got at reasonable cost. If the Sanitary Authority neglect to do this duty, the same proceedings can be taken to make them perform it, under section 299 of the Act of 1875, or, if they are a rural Sanitary Authority, under the Local Government Act, 1894, sections 16 and 19, just as can be taken in the case of their failing to supply the district with sewers. But cases arise

where it is impossible for the Sanitary Authority to supply water at a reasonable cost; under these circumstances they may require the owner to do so, if he can at reasonable cost (Public Health (Water) Act, 1878, section 3). If neither the Sanitary Authority nor the owner can provide water at a reasonable cost, then if the absence of a proper water-supply creates a nuisance so that the house is unfit for habitation, steps may be taken to obtain a justice's order prohibiting its being so used for human habitation (section 97, Public Health Act, 1875).

It was largely to meet difficulties of this kind, especially in rural districts, that the Public Health (Water) Act, 1878, was designed. It applies to every rural Sanitary Authority, and also to such urban Sanitary Authorities as the Local Government Board may order (section 11). Under section 3 of this Act, it is the duty of the local authority to provide or require the provision of sufficient water-supply to every occupied dwelling-house within their district. From time to time they may take steps, by means of systematic inspections on the part of their officers, to see that these conditions are fulfilled. The same powers of entry upon premises are given as are conferred by sections 102 and 103 of the Public Health Act, 1875, in respect of nuisances (section 7); and if the Medical Officer of Health reports that an occupied house is without a proper water-supply, and the Sanitary Authority are of opinion that such a supply can be provided at a reasonable cost (the interest on which, at 5 per cent., shall not exceed twopence a week, or as the Local Government Board may, on the application of the Sanitary Authority, decide to be reasonable in the circumstances), the Sanitary Authority may require the owner, subject to appeal to the Local Government Board, to provide such supply within a specified time, and, in case of default, may themselves carry out the necessary works at his expense. The authority may, on cause being shown why the requirements of the notice served by them should not be complied with, withdraw the notice or modify the terms thereof. Nothing, however, in this Act must be deemed to relieve the Sanitary Authority from the duty imposed upon them by the Public Health Act, 1875, of providing their district or any contributory part of it with a supply of water, where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at a reasonable cost (sections 3 and 4).

In order to prevent houses being built in situations where they cannot be provided with water, the Water Act, 1878, has prohibited (section 6) the owner of any dwelling in a rural district that may be erected or rebuilt from the ground floor after July 4, 1878, from permitting such house to be occupied without a certificate from the Sanitary Authority that it is provided with a sufficient and available supply of wholesome water; such certificate to be based upon the report of the Medical Officer of Health or Sanitary Inspector. Section 9 of the same Act provides that, if the Sanitary Authority furnish a stand-pipe for water-supply, they may make water-charges upon every dwelling within 200 feet, just as if the supply were actually given on the premises; but they may not make this levy upon houses which have a good supply within reasonable distance from another source, unless the water from the stand-pipe is used by the inmates.

The Local Government Act, 1894, section 8 (1) (*e*) empowers a Parish Council to utilise any well, spring, or stream within the parish, and to provide facilities for obtaining water therefrom, consistent with the just rights of any person or corporation; but these powers do not in any way derogate from the obligations of a rural Sanitary Authority in respect of supplying water.

Under the Rivers Pollution Prevention Act, 1876, proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or aggrieved local authority (section 8); but in respect of manufacturing or mining effluents, Sanitary Authorities only can take action, and subject to the approval of the Local Government Board. The Board, in giving or withholding consent, must have regard to the industrial interests involved, and the circumstances and requirements of the locality. They shall not give their consent to proceedings by a Sanitary Authority of a district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the effluents from such manufacturing processes are reasonably practical and available, and that no material injury to the interests of such industry will be caused by the proceedings (section 6).

It is owing to the extensive safeguards which it contains that this Act is so largely inoperative. But it cannot be too clearly understood that, by its provisions, the discharge of solid or liquid sewage, or of any solid matter, into streams, is illegal. Neither may the waste water of houses, which have no water-closets, be discharged without treatment into streams. The discharge of sewage-farm effluents into rivers is a special question, and permissible, provided the effluent is of a certain purity, and not likely to either create a nuisance or pollute any stream or water-course.

In London, the water-supply is now in the hands of the Metropolitan Water Board. This Board controls the water-supply not only in London, but also over a large extra-metropolitan area. Practically the Board has the same position as the provincial water companies, and so far as this question is concerned, neither the County Council nor any other local authority in London has any direct power. The controlling authority, as affecting the public health, over the Board is the Local Government Board, who have the water supplied examined periodically, approve or disapprove of new sources of supply, of various regulations made by the Board for preventing waste, misuse or contamination, and who also inquire into complaints made to them as to the quality or quantity of the water supplied for domestic use.

The Metropolis Water Act, 1871, section 19, gives the County Council power to ask for the repeal or alteration of any of the regulations for the above purposes, and, if the Water Board refuse to do so, to appeal to the Local Government Board, who, on inquiry and report of some impartial engineer or person of engineering knowledge, may make such repeal or alterations as they think fit. Sections 8 and 9 of the same Act have similar provisions as to the County Council asking for a constant supply in any given district. The Water Board cannot, however, be compelled to give a constant supply to any premises in any district until its regulations, as approved by the Local Government Board, are in operation in the district, nor if the former can show that, at any time after two months from the date of the service of any requisition for a constant supply, more than one-fifth of the premises in the district are not supplied with the prescribed fittings. The County Council have power to supply the prescribed fittings on default of owner or occupier. The Local Government Board have power to order a constant supply without application from the County Council, where they think that, by reason of the insufficiency of the existing supply in the district, or the unwholesomeness of such water in consequence of its being improperly stored, the health of the inhabitants is, or is likely to be, prejudicially affected (section 11).

So far as relates to the powers of the metropolitan boroughs and borough

councils in connection with the water-supply, the Public Health (London) Act, 1891, indicates the absence of a proper water-supply, or of proper fittings in a house, to render such house unfit for habitation. A new house must not be occupied until the Sanitary Authority grant a certificate that it has a proper water-supply (section 48). The Water Board cutting off the supply of water to any house must give immediate notice to the Sanitary Authority (section 49). For the closure of polluted wells, &c., the Sanitary Authority have only to satisfy the justice that the water is "so polluted, or likely to be so polluted, as to be injurious or dangerous to health" (section 54). It must be noted that this section gives a Sanitary Authority somewhat greater powers than section 70 of the Public Health Act, 1875, inasmuch as it says not only when the water is so polluted as to be injurious to health, but when it is so polluted, *or likely to be so polluted*, as to be injurious *or dangerous* to health. Moreover, it gives the Court no power to allow the water to be used for certain purposes only, and imposes a fine not exceeding £20 for disobedience to any order under the section.

Every Sanitary Authority under the Act must make bye-laws for cleansing and guarding from pollution tanks, cisterns, and other receptacles for storing water, likely to be used for drinking or domestic purposes (section 50). The Model Bye-laws framed by the Local Government Board in connection with this section demand: (1) the emptying and cleansing of cisterns and tanks once at least in every six months, and at such other times as may be necessary to keep them clean; (2) every such tank, cistern, or receptacle to be provided with a proper cover, and to be kept at all times properly covered. In cases where two or more tenants of a premises are entitled to the common use of any tank, cistern, or receptacle to which this bye-law applies, the foregoing requirements apply to the owner instead of to the occupier of the premises.

In Scotland, the difficulty which exists in England in acquiring a compulsory water-supply by means of a provisional order is not felt, because the Public Health (Scotland) Amendment Acts, 1882 and 1891, apply certain compulsory clauses of the Lands Clauses Acts, not only to the construction of sewers, but also to the provision of a water-supply in landward or rural districts. So soon as a local authority considers a public supply expedient, on representing the facts to the Secretary for Scotland, he is empowered to issue provisional orders (subject to parliamentary confirmation) to bring those clauses into action for the purposes mentioned. The cost of the water-supply either falls, in the form of a water-rate, upon the whole district, or upon any special district according to the circumstances. Special districts may be combined, their area may be altered, and in some cases the special water-rate may be supplemented by a general rate over the whole district.

Burghal water-supplies may be obtained either under the Public Health (Scotland) Act, 1897, or under the Burgh Police (Scotland) Act, 1892. If a water company exists, the local authority may contract with it, or purchase it, but may not enter into competition with it. In larger towns with a population over 10,000, or having a local Police Act, the local authority may provide a water-supply either by contract with a water company, or, where there is no company, directly.

Under the Burgh Police Act, 1892, which does not for these purposes apply to burghs supplied with water before 1895 under local Acts, the Burgh Commissioners of towns having a population below 5000 may apply the compulsory clauses of the Lands Clauses Acts with the consent of the sheriff only, and without a provisional order.

Under section 126, Public Health (Scotland) Act, 1897, the local authority may, if they think fit or consider it expedient to do so, arrange for a supply of water to districts other than burghs, and for this purpose shall be held to have all the powers and rights conferred by the Lands Clauses Acts. The authority may also supply water for baths and wash-houses, but when water is taken for these, it may provide the supply gratuitously.

The Public Health (Scotland) Act, 1897 (section 125), gives power to the local authority to require water to be supplied to houses within its district ; and after giving twelve months' notice to the owner, in default may themselves obtain such supply, and for that purpose may use their powers for acquiring land by agreement or otherwise : Provided that nothing shall relieve the local authority from the duty of providing its district, or any part thereof, with a supply of water when a general scheme for such supply is required, and can be carried out at a reasonable cost.

In Ireland.—The Public Health (Ireland) Act, 1878, enables all Sanitary Authorities to require all houses to be supplied with water " at such cost as the Local Government Board may determine under all the circumstances to be reasonable," there being no limit of cost prescribed as in England (section 72). If the owner, when required by the Sanitary Authority does not execute the necessary works, the Sanitary Authority may do them, and recover the cost summarily, or, if it be an urban Sanitary Authority, the cost may be declared to be private improvement expenses. The Public Health (Water) Act, 1878, not being in force in Ireland, the provisions therein offered cannot be applied.

Another important difference between the Irish and English Acts is that by section 61 of the Irish Act, a Sanitary Authority can acquire the right to abstract water from a running stream or other source otherwise than by agreement. By section 202 every Sanitary Authority is endowed with compulsory powers to acquire water rights for drinking and domestic purposes ; there is a saving clause for the existing water companies (section 62, corresponding to section 52 of the English Act), but it has not stood in the way of amicable arrangements being made between the Sanitary Authorities and the water companies, as to the acquirements by the former of new and additional supplies. The law as to water-rates in Ireland is similar to that in England, except that the levying of such rates is entirely optional with the Sanitary Authority, who, moreover, cannot levy them in respect of either public stand-pipes or street-fountains (section 66).

CHAPTER III

AIR

It might be inferred from the physiological evidence of the paramount importance of proper aeration of the blood, that the breathing of air rendered impure from any cause is hurtful, and that the highest degree of health is only possible when to the other conditions is added that of a proper supply of pure air. Experience strengthens this inference. Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is the most important. Individual observations confirm this. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences, and sometimes even regulates, the second. The average mortality in this country increases, tolerably regularly, with density of population. Density of population usually implies poverty and insufficient food and unhealthy work; but its main concomitant condition is impurity of air from overcrowding, deficiency of cleanliness, and imperfect removal of excreta, and when this condition is removed a very dense and poor population may be perfectly healthy.

The same evidence of the effect of pure and impure air on health and mortality among animals is forthcoming from stables, cow-houses, and kennels where, in proportion to the efforts made to secure cleanliness, dryness and an adequate supply of pure air, has the health and vigour of horses, kine and dogs improved.

The air may affect health by variations in the amount or conditions of its normal constituents, by differences in physical properties or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. In spite of much research we must confess still to considerable ignorance on this subject.

THE COMPOSITION AND PHYSICAL PROPERTIES OF AIR.

The following may be taken as the composition of average air :—

Oxygen	209·6 per 1000 volumes.
Nitrogen	790·0 ,,
Carbonic acid (or carbon dioxide)	0·4 ,,
Watery vapour	varies with temperature.
Ammonia	trace.
Organic matter (in vapour or suspended, organised, unorganised, dead, or living)	variable.
Ozone	variable.
Salts of sodium	variable.
Other mineral substances	variable.

Air, when pure, is free from colour, taste, or smell, and is not a chemical combination of the different factors which compose it, but a mere mechanical mixture. That such is the case is proved by the facts that the gases, of which air is made up, do not exist in it in their proper combining proportions, nor in any multiple of these, and that the relative amounts of these gases in air cannot be expressed by any chemical formula. Moreover, on mixing the gases of which air is composed together in the same proportions as they exist in air, there is no manifestation either of heat, electricity, or change of volume, such as would result were air a chemical compound. The mixing of these constituents is so perfect that analyses of the ordinary outer air, in all parts of the world, give results which vary but little from the above figures. This uniformity of composition is due to the diffusion of gases, to changes of temperature, to the influence of air-currents, and also to the reciprocal action of animals and plants upon air; it obtains, however, only in places where air is free to move in every direction, either by the action of differences of temperature or of winds. In enclosed spaces, like courts, where winds have little or no action, and where decomposition of organic matters is often going on, various substances may be added to air, which, both from their amount and influence upon health, have to be regarded as impurities.

Nitrogen, which is the main constituent of our atmosphere, constitutes 79 per cent. of the air by volume, and 76·9 per cent. by weight. It is a chemical element found everywhere in nature, particularly in the tissues of all animals and plants, and is essential to the existence of all forms of life. In air, nitrogen appears to act as a diluent of the oxygen, evidently reducing its strength and rapidity; it is also probable that it may serve to supply plants with a certain amount of nourishment in the form of oxides, which are washed down out of the air into the soil after storms of rain; but on this point, as yet, very little is known.

The researches of Rayleigh and Ramsey indicate that, of what hitherto has been considered nitrogen in the air, some 1 per cent. is a remarkable elementary gas, termed, by these observers, *argon*. It is the most inert body known, and, so far as has yet been ascertained, cannot be made to combine with any other body. Its atomic weight is apparently 39·8, its density 19·9; its freezing-point is $-189^\circ{\cdot}6$ C., that of nitrogen being -214° C. Argon possesses a double spectrum, in this respect resembling nitrogen and certain other elements.

Oxygen.—Although practically only constituting one-fifth of the atmosphere, oxygen is the most important component of the air, being necessary for the maintenance of every kind of combustion and life. It exists in the air in a free state, and is not chemically combined with the nitrogen of the atmosphere, but only mixed with it. The amount of oxygen in pure mountain air is usually 20·96, by volume, per cent., and 23·20 by weight; while in the air of towns these figures may fall as low as 20·87 and 23·10 respectively.

A modification of oxygen occurs in small traces in the atmosphere, and is known by the name *ozone*. This is a gas considered to be an allotropic form of oxygen, three volumes being condensed into two, thus, $3O_2 = 2O_3$. It is believed to be produced from the oxygen of the air, either by electrical currents generated during thunderstorms, or by weak currents of frictional electricity generated by the friction of large masses of water, such as the sea, against the air, or possibly by the evaporation of water in the presence of sunlight. By whatever process ozone may be produced, it is impossible to convert all the oxygen into ozone, that is, it cannot be obtained in a pure

state, but always contains admixed oxygen, a mixture containing about 20 per cent. of ozone to 80 per cent. of oxygen being about the strongest that has ever been made. It is characterised by a special odour and by having special oxidising powers; it is non-combustible and slightly soluble in water. Owing to the unreliability of methods for testing the presence of this gas, some doubt has risen whether this supposed allotropic oxygen really exists in the free atmosphere. Ilosvay's experiments indicate that many, if not all, of what have been supposed to be the characteristics of ozone in the air are really due to nitrous acid.

Carbon Dioxide.—One of the most conspicuous products which result from the action of oxygen upon animal tissues is the carbon dioxide thrown off from the lungs in the process of respiration. This gas, also known as carbonic acid gas and choke-damp, is always formed when carbon in any form is burnt with a free supply of air. It is one of the gases evolved from volcanoes and in certain places from fissures in the earth, as near Naples and in Java. Under the influence of sunlight, all plants which contain chlorophyll have the power of taking up carbonic acid, making use of it in their tissues, and yielding oxygen to the air as an excretory product. In this way a constancy in the proportion of these gases in the atmosphere is largely maintained. Speaking generally, an average of from 3 to 4 parts in 10,000 parts of air may be taken as the normal amount of carbon dioxide in the atmosphere, but under certain conditions this amount may vary considerably; it is larger in the air immediately above the ground than in air found at an elevation of 8 to 10 feet; it remains fairly constant up to 1000 feet, and then gradually diminishes. The air over the sea contains a much smaller proportion of carbon dioxide than the air over the land: the mean quantity over the ocean is 0·3 per 1000.

Over land, Fodor * gives the limits as 0·200 to 0·600, outside which cases occur very seldom, or depend upon errors; the seasonal range is lowest in winter, an increase in spring, again a diminution in summer, and the highest point is reached in autumn. There is less near the sea-shore and more in the middle of the continent; it appears to increase in snow and frost, but to diminish with rain, thaw, and wind. Fodor attributes the greatest influence on the variation of carbon dioxide in the atmosphere to its rising from the ground air, the carbon dioxide being always greater at the ground level than 1 metre above it. Levy gives the mean carbon dioxide at the observatory of Montsouris as 0·302 per 1000 volumes in a series of five years' observations. In Dundee, Carnelley, Haldane, and Anderson found an average of 0·390—the mean of day-time being 0·380 and night-time 0·410; this was in open places; in close places at night the mean was 0·420.

A tendency is noticeable throughout the later observations upon the amount of carbon dioxide, present in the air, to record a smaller mean proportion than was found by the earlier observers. Reiset's series of determinations made in France in 1872 80 gave an average for day and night of 2·96 volumes per 10,000 of air. Haldane's observations in Perthshire in 1889 -90 show an average of 2·98 in the summer, and of 3·00 in winter per 10,000 of air. In fact, we may say that in the air of the open country the proportion of carbon dioxide averages almost exactly 3 volumes in 10,000 of air.†

Ammonia.—This, the most conspicuous of the nitrogenous products of decomposition, is always present in the air, either free or combined. Most commonly it is only present in the minutest traces; the proportion present

* Fodor: *Hygienische Untersuchungen u. Luft, Boden und Wasser*, Braunschweig, 1881.
† Haldane: "The Air of Factories and Workshops," *Journal of Hygiene*, vol. ii. p. 421.

is at its minimum in winter, increasing in the spring, and being highest in summer. Plant life derives part of its nitrogen from this source. Though the presence of this gas is largely influenced by local conditions, its mean relative proportion may be stated to be 0·03 milligramme in 1 cubic metre of air. Moisture and temperature largely affect the amount of ammonia present in the air; it diminishes regularly with rainy weather and a fall of temperature, and increases as the temperature rises after rain. Fodor has shown that it does not come from the ground air, while observations made in this country indicate that the more densely populated a locality is, and the greater the extent of manufacture going on, the higher is the proportion of atmospheric ammonia. The chief factor in causing irregularities in the relative quantity of ammonia in the air is rain, as with every shower some of it is washed from the atmosphere, as evidenced by its presence in the collected rain-water and its diminution in amount present in the air.

Organic and Suspended Matter.—Though more often to be regarded as an impurity, these matters are rarely absent from normal air. For the most part, they are simple microscopic particles of inorganic matter, existing as dust from the earth's surface, but they may be of organic origin, and, as either moulds, yeasts or bacteria, be not wanting in distinct biological characteristics. The actual amount of this suspended matter in normal air will naturally depend upon local conditions, but it may be generally accepted that, excepting in the air of rooms or hospitals, the organic and suspended matter in the atmosphere is chiefly of an innocent nature.

Watery Vapour is always present in air, the average amount being from 8 to 10 parts per 1000 volumes, but depending, as it does, so much upon temperature and facilities existing for the atmosphere to take up water, this is perhaps the most variable normal constituent of the air. It is very rarely that there is as much vapour in the atmosphere as is possible for it to hold; when such does exist, the air is said to be "saturated"; and in proportion as it is more or less removed from the point of saturation, and not in proportion to the precise amount of water it contains, is air said to be dry or moist. Thus, if air can hold 100 parts of watery vapour, but actually holds only 75 parts, it is said to be only three-quarters moist, or to have 75 per cent. of humidity.

The amount of watery vapour varies greatly in different countries, from about 30 per cent. of saturation to perfect saturation; or, according to temperature, from 1 to 11 or even 12 grains in a cubic foot of air. During the rains in the tropics, that amount is not unfrequently exceeded. The best ratio for health has not been determined, but it has been supposed it should be from 65 to 75 per cent; in many healthy climates, however, it is much more, and in some much less than this.

The following table shows roughly the weight of watery vapour which a cubic foot of air can hold at different temperatures:—

At 10° F.	1·1	grains.		At 65° F.	6·8	grains.
15°	,,	1·3	,,	70°	,,	7·9	,,
20°	,,	1·5	,,	75°	,,	9·2	,,
25°	,,	1·8	,,	80°	,,	10·0	,,
30°	,,	2·1	,,	85°	,,	12·4	,,
35°	,,	2·5	,,	90°	,,	14·3	,,
40°	,,	3·0	,,	95°	,,	16·6	,,
45°	,,	3·6	,,	100°	,,	19·1	,,
50°	,,	4·2	,,	110°	,,	25·5	,,
55°	,,	4·9	,,	120°	,,	34·0	,,
60°	,,	5·8	,,	130°	,,	42·5	,,

Or in another way, it can be said that a quantity of completely moist air at 32° F. holds in suspension an amount of vapour equal to $\frac{1}{160}$th part of its own weight, at 59° F. $\frac{1}{80}$th, at 86° F. $\frac{1}{40}$th, at 113° F. $\frac{1}{20}$th, and at 140° F. $\frac{1}{10}$th. Expressed mathematically, it can be said that while the temperature advances in arithmetical progression, the power of the air to retain vapour increases with the rapidity of a geometrical series having a ratio of two.

When watery vapour mixes with dry air, the volume of the latter is increased ; if the weight of the original volume of dry air be known, it will be found that, for the same volume, the addition of the water vapour has lessened the weight, and that the diminution in weight is proportionate to the amount of vapour added. The weight of a cubic foot of dry air at 50° F., and under a pressure of 29·92 inches of mercury, is 546·8 grains, and that of a cubic foot of vapour at the same temperature and same pressure is 4·10 grains : the two together should weigh 550·9 grains ; but owing to the increase in volume of the air, which the addition of water vapour causes, namely, an increase from unity to 1·0121, we find that a cubic foot of saturated air at 50° F. weighs only 544·3 grains. In other words, dry air is heavier than moist air, and the diminution in weight, which follows the addition of watery vapour, is proportionate to the temperature, because the higher the temperature of the air, the greater is the amount of vapour that it can take up.

Watery vapour, as it exists in the atmosphere, exerts an elastic or expansive force in all directions. This is sometimes called the *tension of aqueous vapour,* and is dependent upon temperature ; it is also capable of doing work, as expressed by the height in inches of a column of mercury which it can support. The elastic force or tendency to escape from containing vessels, which vapour has, increases with a rise in temperature, until the boiling-point of water is reached, when it exactly equals the normal pressure of the atmosphere.

The amount of moisture in the air can be determined by causing a current of air to flow slowly through tubes containing hygroscopic substances, such as caustic potash or hydrochloric acid, and then, by weighing, to note the exact increase in weight which has taken place, and knowing the exact volume of air which has been passed through, to calculate the moisture present as a percentage. It is more usual, however, to determine the atmospheric moisture by means of instruments called " hygrometers," particulars of which are given in a subsequent chapter. The amount of aqueous vapour occurring in the air, at different places, naturally varies very much, less being found inland with a low temperature than out at sea with a high temperature. For the same locality, daily fluctuations of atmospheric humidity take place, depending in most cases upon changes of temperature ; thus on the sea-coast the absolute humidity of the air increases from sunrise until about 2 P.M., when a corresponding diminution sets in and continues until sunrise again. Inland, the same sequence of events occurs during the winter months, but in the summer there is usually a slight fall followed by a rise between the hours of 4 and 6 P.M. After 6 o'clock the decrease of vapour is gradual until sunrise the next morning.

Important as are the facts relating to the chemical composition of the air, still, when considered in special reference to the mechanics and problems of ventilation, the physical properties of air are more important. The reason of this is, that the movements of air currents, with which ventilation is intimately concerned, depend upon differences in weight between adjacent equal volumes of air.

Weight of Air.—That air has weight is shown by the fact that if a glass globe of known capacity be taken, exhausted of all air by means of an air-pump and weighed, its weight then will be less than it would be if air were allowed to enter it. If the capacity of the globe be known, the difference between the two weights is the weight of that volume of air. The weight, however, of a given volume of air differs under varying circumstances. We have already seen how, if the temperature and pressure be the same, a cubic foot of air weighs heavier when dry than when moist. Similarly, if the moisture and pressure be the same, it weighs more at a lower temperature than at a higher one, and its weight increases with the pressure, if the temperature and moisture be the same. Hence to determine the weight of a given volume of air, by comparing it with a standard fixed by experiment, we must know not only the proportion of contained watery vapour, but also the temperature and pressure.

Effects of Temperature.—When air, under constant pressure, is heated, it expands or increases in volume according to a definite law (Charles), which is, that for each degree of temperature added to its heat, it expands a certain constant fraction of its own volume, this fraction being known as the co-efficient of expansion. For each degree Centigrade from 0° to 100°, this co-efficient is for air 0·003667; for each degree on the Fahrenheit scale, between 32° and 212°, it is 0·002036; thus, 1 litre of air at 0° C. will become 1·003667 litre at 1° C., and 1·03667 litre at 10° C.; or at any given temperature t, it will become $1+(0{\cdot}003667t°)$ litre. In the same way, 1 cubic foot of air at 32° F. will be 1·002036 cubic foot at 33° F., and at any given temperature t above 32° F. its volume will be found by the formula, $V=1+(0{\cdot}002036\times(t-32))$. To find, therefore, what the observed volume of air or gas v', at the observed temperature, $t°$ C., would be when reduced to 0° C., we have,

$$v° : v' = 1 : 1+(0{\cdot}003667t°)$$
$$\therefore v° = \frac{v' \,.\, 1}{1+(0{\cdot}003667t°)}.$$

Effects of Pressure.—Under varying conditions of pressure, but a constant temperature, the volume of a gas is inversely proportionate to the pressure (Boyle's law). If a litre of gas at one atmosphere be subjected to the pressure of two atmospheres, its volume will be but half a litre; if the pressure be increased to four atmospheres, the volume will be reduced to one-quarter of a litre, and so on. This can be expressed in another way, thus, if under a pressure of p millimetres or inches of mercury, the volume of air be v, its reduced volume v'', under normal conditions of 760 mm. or 29·92 inches of mercury, may be found by the following equation:—

$$v : v'' = 760 : p$$
$$\therefore v'' = \frac{v \,.\, p}{760}.$$

As the temperature and pressure always exist together, both these factors must be taken into account in reducing volumes of air or gas to standard conditions of temperature and pressure; that is, to 0° C., or 32° F., and to 760 mm. or 29·92 inches of mercury respectively. In actual practice it is more convenient to make these two corrections together, and write a single formula, thus:—

$$v = \frac{v' \,.\, p}{760(1+(0{\cdot}003667t°))},$$ in which

v = volume of air required under normal conditions of temperature and pressure,
v' = observed volume of air,
p = observed pressure under which the air exists.

An example may make this more evident.

Example.—A volume of air at 20° C. and 720 mm. pressure measures 1000 litres; what will be its volume under standard conditions?

Applying the formula, we get,

$$v = \frac{1000 \times 720}{760(1 + (0\cdot003667 \times 20))} = 882\cdot6 \text{ litres.}$$

Although Boyle's law tells us that, the temperature remaining the same, the volume of a given quantity of gas is inversely proportional to the pressure to which it is subjected, still, as the quantity of the gas remains the same, its density must obviously increase as its volume diminishes; therefore, it follows that for the same temperature, the density of a gas, and therefore its weight, is proportional to its pressure. By Charles's law, on the other hand, though the volume increases directly with temperature, the density or weight varies inversely. If we remember, therefore, that a litre of dry air at 0° C. and 760 mm. weighs 1·293 grammes, and that density varies inversely as absolute temperature, and directly as pressure, it is obvious that for any volume v, at any pressure p, and at any temperature $t°$, the weight W will be :—

$$W = \frac{1\cdot293 \times v \times p}{760(1 + (0\cdot003667 \times t))}.$$

Example.—Thus, 1000 litres of dry air which, at 0° C. and 760 mm., weigh 1293 grammes, would only weigh 1141 grammes at 20° C. and 720 mm., because,

$$W = \frac{1\cdot293 \times 1000 \times 720}{760(1 + (0\cdot003667 \times 20))} = 1141 \text{ grammes.}$$

In the case of a volume of moist air, the calculation of the weight is not quite so simple. As this determination involves a knowledge of the hygrometric condition of the atmosphere, and references to tables of the tension of aqueous vapour, it will be more conveniently considered in a subsequent chapter.

Diffusion of Air.—The diffusibility of gases is well known, being, according to the law of Graham, "inversely as the square roots of the densities." Thus, if we take two vessels of equal size, the one containing oxygen and the other hydrogen, and separate them by means of a porous plug, we shall find diffusion take place in the proportion of 4 parts of the hydrogen into the oxygen to every 1 part of the oxygen into the hydrogen. This exact ratio of diffusion is explained by the fact that the density of the hydrogen is 1 as compared with the 16 of the oxygen, consequently the diffusion force is inversely as the square roots of these numbers, that is, it is inversely as 1 is to 4, or just four times as great in the one which has $\frac{1}{16}$th the density the other.

It is this faculty of diffusion, possessed by the air and all gases, which conduces so largely to the composition of air being kept constant, and which enables the carbon dioxide so freely formed in our large towns and cities, by combustion and respiration, to be rapidly removed from where it is formed to other parts where the processes of vegetation and sunlight can break it up into carbon for the food of plant life and oxygen for the use of men. Apart from this, the variations in density of different masses of air play an important part in the maintenance of ventilation.

The velocity with which a mass of air, of known density, diffuses into a vacuum is expressed by the formula, $v = \sqrt{2gh}$; in which h represents the

pressure under which the air flows, expressed in terms of the height of a column of air, which would exert the same pressure as does the effluent air. Thus, if air, under standard pressure, were to flow into a vacuum, this pressure or h is equal to that exerted by a column of air capable of counterpoising the weight of a column of mercury 760 mm. high. As mercury is about 10,500 times denser than air, the equivalent column of air would be $10{,}500 \times 760 = 7980$ metres. In the formula, g represents the accelerative force of gravity per second, being in these latitudes 32 feet or 9·8 metres. The velocity, then, with which air, under ordinary pressure, would flow into a vacuum would be, $v = \sqrt{2 \times 9{\cdot}8 \times 7980} = 395{\cdot}5$ metres per second. This, however, would only be in the first second of time, and owing to a gradual accumulation in the vacuum, a gradual diminution in the difference of pressure between the inside and outside of the vacuum would ensue for each succeeding second. Hence, if during the act of diffusion the pressure in both spaces be noted at certain intervals and be expressed by h, h', the velocity of diffusion at each of these periods would be more correctly calculated from the formula :—

$$v = \sqrt{2 \times g \times (h - h')}.$$

In actual practice, the chief cause of the alterations in the relative densities of the two masses of air, and consequently of their motion, is the elevation in the temperature of one body of air over that of the other ; hence, to determine the velocity with which one diffuses into or rushes to occupy the space of the other, we must further modify the formula, thus :—

$$v = \sqrt{2 \times g \times (h - h') \times (t - t') \times a},$$

in which t is the temperature of the warmer volume and t' that of the colder volume of air ; while a is the co-efficient for expansion of gases.

As we shall see, later on, this formula is purely theoretical, and needs to be only employed after certain corrections for friction, curves, and changes in size or shape of openings have been applied.

Besides the diffusion and movement of adjacent volumes of air, caused by different densities, there is a constant tendency towards diffusion between similar bodies of air, even though apparently separated one from the other. In this case, the current occurs, not through free openings, like doors, windows, or shafts, but through the capillary pores of the separating medium ; and may be from the cooler and denser toward the warmer and rarer body, or *vice versâ*.

IMPURITIES IN AIR.

A vast number of substances, vapours, gases or solid particles continually pass into the atmosphere. Many of these substances can be detected neither by smell nor taste, and are inhaled without any knowledge on the part of those who breathe them. Others are smelt or tasted at first ; but in a short time, if the substance remains in the atmosphere, the nerves lose their delicacy ; so that, in many cases, no warning, and in other instances slight warning only, is given by the senses of these atmospheric impurities.

As if to compensate for this, a constant series of processes occur in the atmosphere or on the earth, which keep the air in a state of purity.

Gases diffuse, and are carried away by winds, and thus become so diluted as to be innocuous ; or are decomposed if compound, or are washed down by rain ; solid substances lifted into the air by winds, or by ascensional force of evaporation, fall by their own weight ; or if organic, are oxidised

into simple compounds, such as water, carbon dioxide, nitric acid, and ammonia ; or dry and break up into impalpable particles, which are washed down by rain. Diffusion, dilution by winds, oxidation, and the fall of rain are the great purifiers ; and, in addition, there is the wonderful laboratory of the vegetable world, which keeps the carbon dioxide of the atmosphere within certain limits. If it were not for these counterbalancing agencies, the atmosphere would soon become too impure for the human race. As it is, it is wonderful how soon the immense impurity, which daily passes into the air, is removed, except when the perverse ingenuity of man opposes some obstacle, or makes too great a demand even upon the purifying powers of Nature.

The air, passing into the lungs in the necessary and automatic process of respiration, is drawn successively through the mouth and nose, the fauces, and the air-tubes. It may consist, according to circumstances, of matters perfectly gaseous (as in pure air), or of a mixture of gases and solid particles, mineral or organic, which have passed into the atmosphere. The truly gaseous substances enter the passages of the lungs, and we can well understand the ease and rapidity with which these gases will enter the blood.

The solid particles entering with the air may lodge in the mouth or nose, or may pass into the lungs, and there decompose, or may remain as sources of irritation until dislodged ; or perhaps become covered over with epithelium like the particles of carbon in the miner's lung. If such particles lodge in the mouth or nose they may be swallowed, and pass into the alimentary canal, and it is even more probable that this should be the case with all except the lightest and most finely divided substances, than that they should pass into the lungs. Although incapable of present proof, there is some reason to think that some of the specific poisons, which float about in an impure atmosphere, such as those which arise from enteric or cholera evacuations, may produce their first effects, not on the lungs or blood, but on the alimentary mucous membrane, with which they are brought into contact when swallowed.

Though no very precise classification can be made of the various impurities which vitiate the air, for practical purposes it is convenient to divide them into (1) Suspended matters ; (2) Gaseous and other offensive substances yielded by factories, workshops, mines, sewers, marshes ; (3) Products from combustion or artificial lighting ; (4) Products from respiration and perspiration.

Suspended Matters.—An immense number of substances, organic or inorganic, may be suspended in the atmosphere. From the soil the winds lift silica, finely powdered silicate of aluminum, carbonate and phosphate of calcium, and peroxide of iron. Volcanoes throw up fine particles of carbon, sand and dried mud, which, passing into the higher regions, may be carried over hundreds or even thousands of miles.

The animal kingdom is represented by the *débris* of the perished creatures which have lived in the atmosphere, while from the vegetable world pass up seeds and *débris* of vegetation, pollen, spores of moulds and bacteria, as well as innumerable volatile substances or gases.

From the sea the wind lifts spray, and the chloride of sodium becoming dried is so diffused through the atmosphere that it is difficult, on spectrum analysis, to find a spectrum without the yellow line of sodium.

The works and habitations of man, however, furnish matters probably of much greater importance from a hygienic point of view.

In the external air, the suspended matters are partly mineral, partly organic. The mineral matters consist largely of silica, iron, chalk, clay,

soot, salt, &c. As rain not only prevents such particles being lifted by the wind, but also washes suspended matters out of the air, it naturally follows that there are more present in the atmosphere during dry weather. The organic suspended matters are principally pollen, algæ, fragments of wood, hair, straw, stable manure, *débris* of insects, &c. In the large manufacturing towns of this and other countries the air is often laden with soot and dust of organic origin, which floats in considerable quantities near the ground surface. Thistleton-Dyer has calculated that in London some 40 hundredweights of soot reach each acre of ground annually from the air in this way. Primrose gives corresponding figures for Glasgow, amounting to 22 hundredweights in summer and 25 in winter. Even in country districts the suspended matters are not inconsiderable in the outer air, such substances as epidermis of hay, fragments of wood, linen and cotton fibres, feathers, carbon, mineral grains, and epithelium having been collected.

The number of bacteria in the external air depends largely upon local conditions, particularly whether there is moisture, nutritive material, and a suitable degree of warmth. They seem to be chiefly derived from the soil surface by the agencies of wind and traffic movements ; this explains why they are so numerous in towns, but comparatively scarce in high mountains, over desert plains, or on the sea. It is not known definitely how far bacteria can be carried by wind, but as dust can be conveyed to an almost indefinite distance, it is not unnatural to presume that bacteria may also be carried over considerable distances, particularly if adhering to dust particles. Dry winds and drought appear to favour an increase of bacteria in air, while moisture lessens them. These results are possibly due partly to an increased dispersion of micro-organisms from the soil in dry weather, and partly to a condensation and sinking of dust by aqueous vapour which washes the air and brings back the greater number of bacteria to the earth. All observations show that in the outer air the pathogenic bacteria are comparatively few as compared with the saprophytic.

In the Dundee experiments of Carnelley, Haldane, and Anderson, the average number of organisms was less than 1 per litre of air ; the proportion of moulds to bacteria being as 1 to 3.

The present state of our knowledge goes to show that in the open air the dilution of bacteria is so great, and the number of pathogenic forms so small, that no danger is to be feared from them unless they originate from local sources of impurity.

Rooms inhabited by Healthy Persons.—In all inhabited rooms which are not perfectly ventilated, the presence of scaly epithelium, cotton, linen and wool fibres, portions of wood, bits of human air, wood, and coal, can be found in addition to the bodies which are present in the external air, though mineral matters and vegetable matters are not so plentiful, as the comparative stillness of the air allows them to fall. Carnelley, Haldane, and Anderson show that there is an enormous increase of *bacteria* in crowded and ill-ventilated rooms, whilst the *moulds* do not increase to the same extent. When the *moulds* and *bacteria* in the external air were as 2 to 6, in houses of four rooms and upwards they were as 4 to 85, in two-roomed houses as 22 to 430, and in one-roomed houses as 12 to 580. These are the actual numbers found per 10 litres of air.

In some cases articles of furniture may furnish certain substances ; the inferior flock wall-papers, coloured green by arsenical preparations, give off little particles of arsenical dust into the room, and in the past have undoubtedly been the cause of some cases of arsenical poisoning.

Sick-rooms.—In addition to being vitiated by respiration, the air of

sick-rooms is contaminated by the abundant exhalations from the bodies of the inmates, and by the effluvia from discharged excretions. The amount of organic matter is known to be large, but it is difficult at present to give a quantitative statement. The peculiar smell of a hospital is indeed very remarkable, and its similarity in hospitals of different kinds seems to show that the odorous substance has a similar composition in many cases.

The scaly epithelia found in most rooms are in large quantity in hospital wards; and probably, in cases where there is much expectoration or exposure of pus or puriform fluids to the air, the quantity would be still larger. In well-ventilated wards, however, the air appears to contain relatively few micro-organisms, but if not well ventilated the air undoubtedly may and does contain specific bacteria given off from the sick. These risks are especially great in rooms occupied by the tuberculous and those suffering from infective forms of pneumonia, erysipelas, and diseases like small-pox and scarlet fever.

Workshops, Factories and Mines.—Grinding of steel and iron, and stones; making metallic and pearl buttons; melting zinc; melting solder; carding and spinning textile fabrics of all kinds; grinding paint; making cement, and in fact almost innumerable trades cause more or less dust, derived from the fabrics and materials, to pass into the air.

Sigerson found a black dust composed of carbon, iron and ash, in metal shops. In the air of a printing office there was enough antimony to be chemically detected. In the air of stables were equine hairs, epithelium, and various fungi.

In addition to these suspended matters, which vary with the kind of work, the air of workshops is largely contaminated by respiration and by the combustion of gas.

In mines the suspended matters are made up of the particles of the particular substance which is being worked, or of rock excavated to obtain metals, of sooty matters from lamps and candles, and of substances derived from blasting.

It is noticeable that in all these cases it is the solid inorganic suspended matters of the air, consisting of dust of various kinds, which are so injurious to health; as a rule, these are only so by virtue of their mechanical irritating influences upon the mucous membranes, particularly the lungs. It is their physical conditions as to roughness, angularity or smoothness, rather than their mere nature, which influences their power for evil; though possibly in some cases they may also serve as vehicles for conveying specific infective disease factors, more especially that of tubercle.

Offensive Gases from Trades.—In the neighbourhood of certain factories or industries more or less dangerous and offensive gases are frequently to be found polluting the air. In some instances these impurities have only the effect of diluting the oxygen in the air, being themselves physiologically harmless. Examples of this exist in the excess of hydrogen and choke-damp in mines, which appear to do more harm by lessening the atmospheric oxygen for respiration than by any special power of their own. In other cases, where many chemical agents are used, extremely noxious gases are frequently emitted into the air. The gaseous waste products of the chief industries are as follows :—

Hydrochloric acid gas, from alkali works.
Sulphur dioxide and sulphuric acid, from copper works—bleaching.
Hydrogen sulphide, from several chemical works, especially those producing ammonia.
Carbon dioxide, carbon monoxide, and hydrogen sulphide, from brick-fields and cement-works.
Carbon monoxide, from iron furnaces, may amount to from 22 to 25 per cent.; from copper furnaces, 15 to 19 per cent.

Organic vapours, from glue refiners, bone-burners, slaughter-houses, knackeries.
Zinc fumes, from brass-founders.
Arsenical fumes, from copper smelting.
Phosphoric fumes, from manufacture of matches.
Carbon disulphide, from some india-rubber works.

The majority of the gaseous products from industries are both irrespirable and offensive, the more markedly hurtful being the vapours of chlorine, iodine, bromine, arsenic and phosphorus, with carbon monoxide, sulphuretted hydrogen, and the compounds of carbon and sulphuric acid. It is true that, unless favoured by particular conditions of wind and weather, in most instances the presence of these gases is not noticed by any one outside the factories in which they are produced; still the majority are so irritating as to constitute, if present in any appreciable quantity, very serious atmospheric impurities.

Air in Mines.—In the metalliferous mines the air is poor in oxygen, and very rich in carbon dioxide. It also contains organic matter, giving, when burnt, the smell of burnt feathers, in uncertain amount. These impurities arise from respiration, combustion from lights, and from gunpowder blasting. This latter process adds to the air, in addition to carbon dioxide, carbon monoxide, hydrogen and hydrogen sulphide, various solid particles, consisting of suspended salts, which may amount to as much as 6 or 7 milligrammes in each cubic metre of air. These suspended substances are principally potassium sulphate, carbonate, hyposulphite, sulphide, sulphocyanide, and nitrate, carbon, sulphur, and ammonium sesquicarbonate. Much of this may be avoided by the process of getting coal by means of compressed quicklime, which is slaked in holes drilled in the coal.

Recent investigations upon the air of coal-mines show that the average amount of carbon dioxide present exceeds 2 parts per 1000 of air, and that the oxygen often falls to as little as 200 per 1000 of air. In shallow pits the air at the bottom of the downcast shaft appears to be very good indeed, but in the deeper pits the air samples were never as good as obtained from shallow ones. The oxidisable matter seems to vary, but the methods available for this determination explain the differences in the different results. Although micrococci and bacteria, as well as yeasts and moulds, were readily demonstrated as being present in large numbers in the air of all mines, still the micro-organisms do not seem to follow any fixed rule, as in one very bad sample of air, as regards carbon dioxide, there were none, while the same air soon after yielded twenty colonies per litre. In mines, stagnation of air and high temperature are favourable circumstances for their growth, but the presence of men and horses are more potent factors.

The relative humidity of the air in mines varies from 85 to 95 per cent.; practically, it is nearly always saturated. This excessive humidity is certainly not desirable from a sanitary point of view, but there is no evidence that it conduces to bad health among the miners. The temperature of mine air is wonderfully uniform, there being neither the great vicissitudes of temperature as above ground nor the frosts.

Haldane's inquiries into the cause of death in mines after explosions show that death chiefly results from suffocation due to the deficiency of oxygen, which becomes displaced by the products of the explosion, *i.e.*, after-damp. Suffocation by deficiency of oxygen occurs when the respired air contains less than 8 per cent. of oxygen, being ushered in by an extremely sudden attack of muscular paralysis, so that there is little warning of the danger when air is inspired deficient in oxygen, and little chance of escape owing to the muscular failure. Suffocation through excess of carbon

dioxide is quite different, as it is preceded by gradual respiratory distress in which the neuro-muscular system is aroused to greater activity. In mines, after explosions, in addition to the deficiency of oxygen, danger exists from the after-damp containing often at least two noxious gases in fatal quantities, these being carbon monoxide and hydrogen sulphide.

Black-damp, sometimes also called choke-damp, is one of the gases often found in coal-mines. It is distinguished from fire-damp by the fact that it is not explosive when mixed with air, but extinguishes fire, and from after-damp by the fact that it is not the product of an explosion, but collects in the workings under ordinary conditions. Like fire-damp and after-damp, it produces fatal effects when inhaled in sufficient concentration. Haldane's observations show that undiluted black-damp consists of nitrogen containing a seventh of its volume of carbonic acid. A mixture of about 16 per cent. of black-damp and 84 per cent. of air extinguishes lights, whereas a mixture of about 60 per cent. of the black-damp and 40 per cent. of air are required to produce immediate danger to life. Black-damp is the residual gas left on slow oxidation of the carbon and hydrogen of coal by air. Its dangerous physiological action is due to deficiency of oxygen, not to excess of carbonic acid. The effect first appreciable when increasing proportions of black-damp are breathed is due, however, to carbonic acid alone.

Air of Sewers.—The air of cesspools, and especially of the cemented pits, which are still common in many continental towns, and which receive little beyond the solid and liquid excreta and some of the house water, is generally highly impure.

In sewers the products of decomposition are variable, as not only solid and liquid excreta and house water, but the washings and *débris* of the streets, the refuse of trades, &c., pass into the sewers. As a rule, the products of decomposition of sewage appear to be much the same as noted above—viz., fœtid organic matters, carbo-ammoniacal substances condensing with the water of the air on the cold walls, carbon dioxide, nitrogen, and hydrogen sulphide. The combinations of these gases are variable; the most common are carbon dioxide and nitrogen; marsh gas is found when oxidation is impeded, and hydrogen sulphide and ammonium sulphide, which form in the sewage in most cases, are liberated from time to time. The gases, however, are, as a rule, of far less importance than the associated micro-organisms.

The composition of sewer air varies considerably, depending upon the degree of ventilation and the efficiency of the flow of the sewage. From time to time a number of analyses of sewer air have been made, these show that in fairly well-constructed sewers the carbon dioxide is not greatly in excess, and that there are often but the merest traces of sulphuretted hydrogen and of offensive organic matter. Carnelley and Haldane's experiments on the air in the sewers of the Houses of Parliament, and in Dundee, led them to the following conclusions:—(1) That the air of the sewers was much better than might have been expected; (2) that the carbonic acid was about twice, and the organic matter rather more than three times, as great as in the outside air at the same time, whereas the number of micro-organisms was less; (3) that, in reference to the *quantity* of these three constituents, the sewer air was in a very much better condition than that of naturally ventilated schools, and that, with the notable exception of organic matter, it had likewise the advantage of mechanically ventilated schools; (4) that the sewer air contained a much smaller number of organisms than any class of house. In the Westminster sewer, they found the carbon dioxide to range from 5 to 9 parts per 10,000 volumes, and the oxygen

required for oxidisable matter to vary from 1 to 13 volumes per million, and the micro-organisms from 1 to 38 per litre. These observations have been confirmed by Parry-Laws.*

The more recent observations of Andrewes and Hurtley † on the air of the sewers of Hampstead indicate the carbon dioxide to have ranged from 10 to 17 volumes in 10,000 of air; the sulphuretted hydrogen was almost inappreciable, while the ammonia amounted to 0·05 grains in a million litres of air. The micro-organisms averaged only 1 per litre. Their investigations show that, at Hampstead at least, the sewer air during the day is distinctly fouler than that of the outer air, but that during the night it is practically indistinguishable from that of the outer air. This fact they attribute to sewer air being nearly always saturated with water vapour, and any fall in temperature leads to rapid condensation. The carbon dioxide being feebly soluble in water is little affected by this condensation, while ammonia and sulphuretted hydrogen, being more soluble, are constantly removed. Bacteria and other particulate matter forming nuclei round which water vapour condenses are also removed largely along with the soluble gases from sewer air whenever condensation of water vapour occurs. Although the weight of evidence shows the air of sewers to be not unduly foul, still the state of the air in a large sewer can hardly indicate the true condition of that in all the drains connected with it; from this point of view we think the matter needs further investigation.

Air of Marshes.—The air of typical marshes contains usually an excess of carbon dioxide, which amounts, perhaps, to 0·6 or 0·8 or more per 1000 volumes. Watery vapour is usually in large quantity. Hydrogen sulphide is present, if the water of the marsh contains sulphates, which in presence of organic matter are converted into sulphides, from which sulphuretted hydrogen is derived by the action of vegetable acids. Marsh gas is also often present, and occasionally free hydrogen and ammonia, and, it is said, hydrogen phosphide.

Impurities from Fires and Artificial Lights.—As coal is the chief material used for combustion in our fires, it constitutes the main source of impurities to the atmosphere from various means of heating. For the complete combustion of 1 lb. of coal at least 160 cubic feet of air are required by theory, but in actual practice from half to twice as much air again must be supplied, making the average amount required per pound of coal to be from 240 to 320 cubic feet. During combustion about 1 per cent. of the coal is given off into the air as soot and tarry products, with large quantities of carbon dioxide and carbon monoxide. The actual amounts of these gases given off will depend upon the degree of perfection of the combustion; but it has been calculated that for every ton of coal burnt in London something like three tons of carbon dioxide are produced. In addition to these impurities, the atmosphere receives from the burning of coal, carbon disulphide, ammonium sulphide, water, and occasionally sulphuretted hydrogen, as well as sulphur, sulphur dioxide, and sulphuric acid. Ordinary coal contains from ½ to 7 per cent. of sulphur, and it is not unusual to find in the outer air, in manufacturing districts, from ½ to 1 grain of sulphuric acid per 1000 cubic feet of air.

Wood produces, on combustion, carbon dioxide and monoxide, with more water but less sulphur compounds than coal does. The impurities

* Parry-Laws: *On the Ventilation and Condition of London Sewers*, Report to London County Council, 1894.

† Andrewes and Hurtley: Report on Bacteriological and Chemical Investigations of the Sewer Air of Hampstead, 1905.

from coke and peat are somewhat similar to those from coal. In cases where the combustion is incomplete or the supply of oxygen is insufficient, much of the carbon becomes incandescent in an atmosphere highly charged with, and practically consisting of, carbon dioxide, combining with it to form carbon monoxide, thus, $C_2+2CO_2=4CO$. The blue flames so often seen at the top of a well-drawing clear fire consist of burning carbon monoxide, which has been produced by the carbon dioxide, formed at the lower part of the fire, having to pass over the red-hot coal on its upward way to the chimney. This carbon monoxide is largely given off from charcoal fires and "slow combustion" stoves, and is, moreover, very much more poisonous than the dioxide.

The products of the combustion of coal and wood pass into the atmosphere, and usually are at once largely diluted. Diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide. It is not so, however, with the suspended carbon and tarry matters, which are too heavy to drift far or to ascend high. As a rule, the particles of carbon are not found higher than 600 feet; and the way they accumulate in the lower strata of the atmosphere can be seen by looking at any lofty building in London. The air of London is so loaded with carbon, that even when there is no fog, particles can be collected on an aeroscope when only a very small quantity of air is drawn through. Sulphurous and sulphuric acids also appear to be less rapidly removed, and rain-water is often made acid from this cause.

With regard to the impurities added to the air, consequent on artificial lighting, we find that the chief sources of light are candles, oil, and coal gas, and that the chief products from the more or less complete combustion of these illuminants are carbon dioxide and water, with the addition, in the case of gas, of several products from the combustion of sulphur. Now the unit adopted in this country for the measurement and comparison of all lights is a sperm candle of a size known as "sixes," burning 120 grains per hour, and which gives a light known as "one candle-power." Such a candle, on analysis, contains:—Carbon, 80·0 per cent.; hydrogen, 13·0 per cent.; oxygen, 6·0 per cent.; and, on complete combustion, yields equal volumes of carbonic acid and water to the air, namely, 0·41 cubic foot.

The French unit of light is the light given out by one Carcel burner, and equals 9·3 English standard candles.

Although various kinds of oil have been employed for illuminating purposes, paraffin, owing to its cheapness and high illuminating value, is the only one now in extensive use. Ordinary paraffin, on analysis, gives the following composition:—Carbon, 86·0 per cent.; hydrogen, 14·0 per cent.

When burnt in the better kinds of lamps, the average consumption per candle-power of this oil is just 62 grains per hour, giving off on combustion in that time 0·28 cubic foot of carbonic acid and 0·22 of a cubic foot of water vapour. In the inferior class of lamps, the consumption of oil is often double the above amount, accompanied by the production of 0·5 of a cubic foot of carbon dioxide and the consumption of the oxygen of about 3·2 cubic feet of air.

The chief popular illuminant is coal gas. Ordinary coal gas is a mixture of gases, consisting mainly of hydrogen and hydrocarbons, produced by the dry or destructive distillation of coal. The coal is heated, without contact with air, in iron retorts, and the products of its destructive distillation are made to pass, first, through condensers in which, as a result of the cooling they are subjected to, the heavy coal tar and the lighter ammoniacal tar-

liquor are condensed, and are then collected in tanks; and secondly, the gas is led through purifying chambers, containing either moist slaked lime or ferric oxyhydrate spread on shelves, either of which removes the gaseous impurities containing sulphur, the former removing carbon dioxide as well; finally the gas is passed into a gasometer for storing purposes.

The following statement of the analysis of two London gases may be accepted as fairly representing the composition of coal gas generally :—

	A.		B.
Hydrogen	50·16	..	53·36
Saturated hydrocarbons	36·25	..	32·69
Unsaturated hydrocarbons	3·50	..	3·58
Carbon monoxide	5·68	..	7·05
Carbon dioxide	0·00	..	0·61
Nitrogen	4·10	..	2·50
Oxygen	0·31	..	0·21
	100·00	..	100·00

In some analyses, the carbon monoxide has been found as high as 11 per cent., and the light carburetted hydrogen 56; in such cases the amount of hydrogen is small. As a rule, English coal gas contains less than 20 grains of sulphur per 100 cubic feet, or 0·46 gramme per cubic metre. For London, the maximum is at present 17 grains in summer and 22 grains in winter; in many provincial towns the gas contains as much as 30 or 40 grains per 100 cubic feet. In crude unpurified gas, the sulphur is present chiefly as sulphuretted hydrogen, about $\frac{1}{10}$th being in other forms, chiefly as carbon bisulphide. During purification, both these are removed.

The constituents of coal gas may be divided into three groups, *diluents*, *illuminants*, and *impurities*. The diluents are gases which, without conferring much luminosity on coal gas when burnt, yet serve the important purpose of diluting down the heavy hydrocarbons, which by themselves would yield a smoky flame; the diluents are hydrogen, methane, or marsh gas, and carbonic oxide; they constitute about 90 per cent. by volume of the coal gas. The illuminants are hydrocarbon gases or vapours rich in carbon, and to their presence the luminosity of coal gas when burnt is due; they are ethene or olefiant gas, acetylene, and benzene vapour; they constitute about 6 per cent. by volume of the coal gas. The impurities constitute the remaining four volumes, and consist of nitrogen derived from a little air getting into the retorts when opened for recharging, and of some carbon dioxide, with traces of sulphur compounds which may have escaped removal in the purifiers.

When the gas is partly burnt, the hydrogen and light and heavy carburetted hydrogens are almost destroyed; nitrogen (67 per cent.), water (16 per cent.), carbon dioxide (7 per cent.), and carbon monoxide (5 to 6 per cent.), with sulphur dioxide and ammonia, being the principal resultants. And these products escape usually into the air of rooms. With perfect combustion there will be little carbon monoxide.

Every cubic foot of ordinary coal gas yields, on combustion, roughly half its own volume, or 0·52 cubic foot of carbon dioxide, and 1·34 cubic foot of water vapour; therefore, knowing how much gas per hour each burner consumes, the average being from 3 to 6 cubic feet, there is no difficulty in calculating the vitiation of air from these sources. Combustion, however, in ordinary burners is never absolutely complete; and even with a 16-candle gas very slight traces of carbon monoxide will generally escape combustion, whilst with a rich gas distinct traces of acetylene are also given off. In other words, the actual products of combustion given off by gas will vary much with the quality of the gas used and the completeness of the process;

the usual products being carbon dioxide, carbon monoxide, compounds of ammonia, watery vapour, and various compounds of sulphur. These latter, if present, are particularly injurious to health, in fact Haldane * maintains that the unpleasantness of air vitiated by the products of the combustion of lighting gas is due to the presence of sulphur in gas, and varies in proportion to the amount of sulphur. Gas which is purified from carbon bisulphide is hygienically superior to gas which is purified only from sulphuretted hydrogen. For every 100 cubic feet of gas consumed, containing 20 grains of sulphur, there would be 0·032 cubic foot of sulphur dioxide formed, while with an impurer gas, containing 30 grains of sulphur per 100 cubic feet, the sulphur dioxide resulting would amount to 0·048 cubic foot. Except under very unusual circumstances, ventilation would reduce these quantities, and, according to Rideal,† it is only when a room is so vitiated that the carbon dioxide has reached 50 volumes per 10,000 that the sulphur content of the air will exceed the limit of perception even with 40-grain gas. Our own observations indicate that with 35 grains of sulphur per 100 cubic feet of gas, there is a distinct taste of sulphur and irritation of the air passages when the carbon dioxide reaches 17 volumes per 10,000. With the same gas, fog resulted when the air was 85 per cent. saturated with moisture.

Speaking generally, it may be said that each cubic foot of gas, burnt per hour from the ordinary burners, vitiates as much air as would be rendered impure by the respirations of an individual; it, at the same time, will raise the temperature of 31,290 cubic feet of air 1° F., and yields 217 calories (a kilogramme of water heated 1° C.), or 860 British heat units (a pound of water heated 1° F.). The following table shows the relative amounts of oxygen removed from the air, and carbon dioxide, watery vapour, and heat calories produced, per hour, by various forms of artificial light; with these facts are also incorporated the candle-power, and the number of adults who would exhale the same amount of carbon dioxide in the same time.

	Quantity consumed.	Candle-power.	Oxygen removed.	CO_2 produced.	Moisture produced.	Heat Calories produced.	Vitiation equal to Adults.
Tallow candles . .	2200 grains	16	10·7 c. ft.	7·3 c. ft.	8·2 c. ft.	1400	12·0
Sperm candles . .	1740 „	16	9·6 „	6·5 „	6·5 „	1137	11·0
Paraffin oil lamp . .	992 „	16	6·2 „	4·5 „	3·5 „	1030	7·5
Kerosene oil lamp .	909 „	16	5·9 „	4·1 „	3·3 „	1030	7·0
Coal gas, No. 5 batswing burner . .	5·5 c. ft.	16	6·5 „	2·8 „	7·3 „	1194	5·0
Coal gas, Argand burner . . .	4·8 „	16	5·8 „	2·6 „	6·4 „	1240	4·3
Coal gas, regenerative burner . . .	3·2 „	32	3·6 „	1·7 „	4·2 „	760	2·8
Coal gas, Welsbach incandescent . .	3·5 „	50	4·1 „	1·8 „	4·7 „	763	3·0
Electric incandescent light . . .	0·3 lb. coal	16	0·0 „	0·0 „	0·0 „	37	0·0

It is sufficiently obvious from the above facts that the most hygienic source of light is the electric incandescent lamp, inasmuch as all other sources of artificial illumination, being dependent on the absorption of oxygen from the air, result in the vitiation of the atmosphere by products which are more or less injurious to health. The electric arc light, which is not con-

* Haldane: "Sulphur in Lighting Gas," *Journal of Hygiene*, vol. iii. p. 382.

† Rideal: Report of Departmental Committee on Gas Testing for the Metropolis, 1904, p. 102.

tained in a closed globe, is said to vitiate the air by the formation of nitric acid, but even if so, its effects in this direction are much less hurtful than gas, oil, or candles.

Of the various forms of light derived from coal gas, that yielded by the Welsbach or incandescent gas-burner stands out pre-eminently as the best. From the hygienic standpoint it is simply an ordinary Bunsen burner, over the flame of which is hung a network of incombustible material that is intensely luminous when raised to the temperature of the flame. It is noticeable that the vitiation of air with carbon dioxide by one Welsbach burner, giving a 50-candle-power light and consuming 3·5 cubic feet of gas, is less than one-half that produced by an oil lamp of 16 candle-power, and consuming a little over 2 ounces of oil. Further, "while the increase of carbon dioxide per candle-power is only 0·365 in the case of the incandescent or Welsbach light, it is 1·9 in the case of Argand burners, 2·86 in the batswing, and 1·6 in oil lamps"; and the increase of temperature in a room with a Welsbach burner per candle-power is "only 0·116° compared with the Argand, 0·59°, the batswing, 0·807°, and oil lamps, 0·468°." *

Acetylene has claimed public attention for the last few years as an illuminant. Powdered coal and coke, mixed together in equal parts and fused under the influence of a very high temperature, enter into combination, forming the compound known as carbide of calcium. This substance undergoes an energetic chemical action with water, resulting in the formation of lime, and the gaseous hydrocarbon, *acetylene*; compared with ordinary coal gas of 16 candles, acetylene shows an illuminating power of 240 candles. The light obtained from acetylene is a very brilliant white light, the gas being burnt in flat-flame burners with very diminutive orifices. It is distinguished from coal gas by the absence of any internal blue flame, such as is usually noticed near a gas-burner.

The most essential condition required with the use of this illuminant is the absolute soundness of the gas-fittings inside the house, as an escape of acetylene gas is fraught with grave consequences; when inhaled it acts injuriously upon the hæmoglobin of the blood, and there is some danger of explosion. It is noticeable that equal parts of acetylene and coal gas will not produce an explosive compound; the mixture will merely burn. As the quantity of air is increased the mixture becomes gradually more explosive, and the maximum point of explosive danger is reached when there is 1 volume of acetylene to 12 of air. Beyond this point the addition of air gradually diminishes the explosive effect, until when there is only 1 volume of acetylene to 20 of air, the mixture is harmless.†

The adoption in recent years by municipal and private gas companies of carburetted water gas as a substitute for, or as an admixture of, illuminating gas gives rise to some important questions from the point of view of public health; these points have reference mainly to increased risks of danger to health and life owing to the increased presence of carbon monoxide in the atmosphere where this gas is burnt. The chief reasons which prompt the use of water gas are the economy and simplicity of its production.

Water gas and producer gas are in extensive use as motive-power of gas-engines and for heating purposes, whereas carburetted gas is used either alone or mixed with coal gas for lighting purposes. *Producer gas* or *Dowson gas* is made by passing air, or a mixture of air and steam, through incandescent coke or anthracite coal in a furnace generator or retort. The carbon must have a temperature of 2000° F. to attain the maximum production of gas.

* "Report on Artificial Lights and Gas Burners," *Lancet*, Jan. 5, 1895.

† Masi: *Annali del Instituto d'Igiene dell' Universita di Roma*, 1903.

The product consists of a mixture of hydrogen, nitrogen, marsh gas and carbon monoxide, with carbon dioxide as the chief impurity. *Water gas* is made in the same way, except that steam only is passed through the incandescent coke, the product being chiefly carbon monoxide and hydrogen. If the temperature of the carbon be much lower than 2000° F., there is a relative increase of carbon dioxide; temperature of production, therefore, has an important influence on the percentage amounts of the two oxides of carbon in the compound produced, and as the monoxide is the desideratum, regulation of the temperature of the carbon is of importance. *Carburetted gas*, or carburetted water gas as it is often called, is a different product from both the foregoing. It is made by passing water gas, manufactured as above, over a large surface of heated refractory material charged with oils rich in hydrocarbons. The effect of this procedure is that the more volatile hydrocarbons are vapourised and thereby mixed with the water gas, the resultant product being what is called carburetted gas. The incorporated volatile hydrocarbons are mainly benzene and its congeners, and they impart to the carburetted gas an odour very similar to that characteristic of ordinary coal gas.

From the public health point of view, the chief difference in the composition of producer gas, water gas and carburetted gas when contrasted with coal gas, is the relatively much higher proportional amounts of carbon monoxide which they contain. Coal gas, for example, may be said to contain on the average from 6 to 9 per cent. of carbon monoxide, whereas producer gas or water gas contains as much as from 25 to 50 per cent., and carburetted gas about 30 per cent. By reason, therefore, of the large increases of carbon monoxide in these last-named products, it will be perceived how, in certain circumstances of exposure to leakage, risks to health and danger to life are substantially increased by the use of the former, as compared with the use of gas made solely from coal. This question has been discussed by Glaister,* who urges the adoption of the finding of a Departmental Committee † that the proportion of carburetted gas in the night supply of coal gas should be limited to 12 per cent. When we consider the want of average display of intelligence on the part of some users of gas, and the condition of the fittings in many places, we cannot but consider the proposal as reasonable, and even go further and urge, with Glaister, that the purveying of gas, rich in carburetted water gas, should be accompanied by inspection of all gas-fittings inside dwellings, just as there is power of inspection over pipes outside dwellings. In all modern bye-laws respecting the water-supply of houses, the local authority has power to determine what weight of pipes and what kind of fittings shall be used. Logically, if the Legislature believes it to be desirable to grant powers of inspection of and control over the sanitary fittings of a dwelling, such as water- and drain-pipes, where the risks from want of soundness are relatively indirect, it should give also powers of control of gas-fittings for the use of carburetted gas or coal gas with which carburetted water gas is mixed, and where the risks to health from defects or insufficiency of fittings are direct.

Of all the systems of artificial lighting in common use at the present time we are bound to place, for reasons already detailed, the incandescent electric light in the first rank from the point of view of health. "From the same point of view, we place next the incandescent gas-light. It is less productive of carbon dioxide than the average oil lamp, and consumes not quite

* Glaister: "Water Gas, Carburetted Water Gas and Carbon Monoxide Poisoning," *Lancet*, 1906, vol. ii. pp. 1578 and 1649.

† Report of the Departmental Committee on Water Gas, 1899.

one-half less gas than the ordinary burners, giving rise, therefore, to the evolution of half the heat, and half the amount of carbon dioxide, while its illuminating power expressed in candles is more than three times as great as the best ordinary gas-burners or incandescent electric light, each of which rarely exceed 16 candle-power." The only gas-light which at all approached it, in its hygienic advantages, is Siemens's regenerative burner, but that has one-third less illuminating power, and is less well adapted for general domestic use. The relative merits of the other forms of artificial light are sufficiently manifest from the figures given to require no special criticism.

Carnelley and Mackie have shown that the combustion of coal exercises a marked effect on the organic matter in the air of towns; but that the combustion of coal gas in a room has not much effect on increasing the organic matter, whereas a burning oil lamp has a marked effect.

Summing up, we may say that the chief changes produced in the air by the use of artificial lights are elevation in temperature, the addition of moisture, carbonic oxide, carbon dioxide, nitric and nitrous acid, compounds of ammonia, and of sulphur, marsh gas, carbon particles and acids of the fatty group. Apart from these added impurities, the air suffers by the withdrawal of a certain amount of oxygen.

Impurities from Respiration.—It will materially aid our conception of the nature and amount of the impurities added to the air by respiration if we contrast the chemical composition of 100 parts of ordinary atmosphere with 100 parts of expired air, in respect of their chief constituents.

	Ordinary Air.	Expired Air.
Oxygen	20·96	16·40
Nitrogen	79·00	79·19
Carbon dioxide	0·04	4·41

From this it will be seen that the expired air contains more than 100 times more carbon dioxide, nearly 5 per cent. less oxygen, and a small amount of nitrogen, more than the atmospheric air. Hence, during respiration more oxygen is taken into the body from the air than carbon dioxide is given off; so that the volume of the expired air is from $\frac{1}{40}$th to $\frac{1}{50}$th smaller than the volume of the air inspired, both being calculated as dry, at the same temperature and pressure. This diminution of the volume of expired air is, however, far more than compensated by the warming which the inspired air undergoes in the respiratory passages, so that eventually the volume of the expired air is really $\frac{1}{9}$th greater than the air inspired. The changes produced, therefore, in air by respiration are, elevation in temperature, increase of moisture, increase in volume and changes in chemical composition.

An average adult gives out at each respiration 22 cubic inches of air, and, assuming that he breathes eighteen times a minute, the total quantity of air which passes out of the lungs in the twenty-four hours is 570,240 cubic inches, or 330 cubic feet. If we further assume that the expired air contains 4·4 per cent. of *carbon dioxide*, the average adult at rest evolves 14·52 cubic feet of this gas in the twenty-four hours, or 0·6 cubic foot per hour; this amount is, however, largely increased by exertion, and may, in the case of a man doing hard work, reach 37 cubic feet in the twenty-four hours, or, say, 1·6 cubic foot of carbon dioxide exhaled per hour. In the case of big men, say 12 stones in weight and at rest, the carbon dioxide given off hourly from the lungs is not less than 0·72 cubic foot. Women give off less, about 0·6; while children and old people give off a smaller amount. The quantity given off by women, say 0·6, may be adopted for a mixed community.

The amount of carbon dioxide in pure air being assumed to be on an average 0·4 per 1000, the quantity in the air of the rooms vitiated by respiration varies within wide limits, and many analyses will be found in books ranging from as little as 0·45 to 3·1 parts of carbon dioxide per 1000 of air. The carbon dioxide of respiration is equally diffused through the air of a room, being rapidly got rid of by opening windows, and in this respect differs from the organic matter and watery vapour, neither of which appears to diffuse rapidly or equably through a room.

The amount of *water* given off to the air by respiration of course varies with the temperature and condition of humidity of the inspired air, as well as with the size of, and work being done by, each individual; but as an average for twenty-four hours, the amount may be taken as being 10 ounces, or 284 grammes. To this must be added some 20 ounces more of moisture given off by the skin. This is equivalent to about 550 grains per hour. If we assume the average temperature of occupied rooms to be 15°.6 C. (=60° F.), this means that enough moisture is given off by the human body, in repose, every hour sufficient to saturate 90 cubic feet of air. It is this tendency to become saturated with moisture from the lungs and skin that makes the air of crowded rooms so uncomfortable. Carnelley's experiments show that for every part of carbon dioxide found in the air, 2·7 volumes, or 1·1 part by weight, of moisture have been given off by each person inhabiting the room.

The *organic matters* contained in expired air are small in quantity and of unknown nature. If a large quantity of such air be drawn through distilled water, or if its moisture be condensed by cold, the liquid thus produced contains nitrogenous matter, has a peculiar, unpleasant odour, and usually soon putrefies. This organic matter is apparently partly suspended, and is made up of small particles of epithelium and fatty matters detached from the skin and mouth, and partly of an organic vapour from the lungs and mouth. The organic matter from the lungs, when drawn through sulphuric acid, darkens it; through permanganate of potash, decolourises it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapour on the sides of a globe containing ice, it is found to be precipitated by nitrate of silver, to decolourise potassium permanganate, to blacken on platinum, and to yield ammonia. It is therefore nitrogenous and oxidisable. It has a very fœtid smell, and this is retained in a room for so long a time, sometimes for four hours, even when there is free ventilation, as to show that it is oxidised slowly. It is probably in combination with water, for most hygroscopic substances absorb it largely. It is probably not a gas, but is molecular, and floats in clouds through the air, as the odour is evidently not always equally diffused through a room. In a room, the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the carbon dioxide reaches 0·8 per 1000 volumes, and is very strong when the carbon dioxide amounts to 1 per 1000. Carnelley, Haldane, and Anderson found that there was a general relationship, so that a high ratio of carbon dioxide is, as a rule, accompanied by a high organic matter figure, and *vice versâ*, although this is by no means always the case.

When the air of inhabited rooms is drawn through pure water, and the free ammonia got rid of, distillation with alkaline permanganate, by the method of Wanklyn, gives a perceptible quantity of "albuminoid ammonia."

In their experiments, Carnelley, Haldane, and Anderson state the organic matter in volumes of oxygen required to oxidise it per 1,000,000. This is equal to c.c. per cubic metre, each c.c. of oxygen weighing 1·43 of a milli-

gramme. The results are much higher than those of previous observers, the mean oxygen for organic matter in the external air in the town being 8·9, and in the suburbs 2·8 volumes per 1,000,000; they would equal 12·7 and 4 milligrammes respectively. In dwellings it was found to increase, though not to the marked extent that was observed in *bacteria*, but the increase was sufficiently proportionate to the carbon dioxide to support the view that they are generally coincident, although varying much in individual cases. On the other hand, there seems little relation between the carbon dioxide and the number of micro-organisms.

In 1888, Brown-Séquard and d'Arsonval reported, as the result of repeated experiments, that the condensed liquid from expired air contains a volatile poison resembling a ptomaine; and if a few cubic centimetres of this liquid be injected into rabbits they rapidly die. Earlier observers had obtained similar results by enclosing animals in glass cases, absorbing the carbon dioxide produced, and supplying oxygen: yet death ensued.

The experimental results of Hermann, Dastre, Loye, and others are suggestive of the condensed fluid being without any toxic qualities. Lehmann and Jessen state that neither the condensed vapour of expired air nor its distillate, when injected either subcutaneously or into the peritoneal cavity of rabbits, has any effect upon their health. They have also shown that individuals can inspire with impunity air that has passed through the condensed vapour of expiration. According to them, no analytical methods at their disposal could detect the presence of poisonous alkaloids in the water condensed from expired air; it contains, however, traces of ammonia, small portions of organic matter, some hydrochloric acid, and yields a peculiar odour on being heated.

On the other hand, Merkel has published an account of experiments which appear to be inconsistent with the belief that no volatile poison, other than carbon dioxide, is present in expired air. The more recent investigations upon this point in this country, notably by Haldane and Smith at Oxford, indicate that the results by both the injection and ventilation methods of Brown-Séquard, d'Arsonval, and Merkel must be capable of some other interpretation than that expired air contains organic matter which is of the nature of a volatile poison. Their chief conclusions are to the effect that (1) the immediate dangers from breathing air highly vitiated by respiration arise from the excess of carbonic acid and deficiency of oxygen, and not from any special poison; (2) that any hyperpnœa which ensues is due to excess of carbon dioxide, and not to the corresponding deficiency of oxygen; the hyperpnœa usually appears when the carbon dioxide is present to the extent of from 3 to 4 per cent.; (3) that the frontal headache so commonly produced by vitiated air is due to the excess of carbon dioxide; (4) that hyperpnœa from defect of oxygen begins to be appreciable when the oxygen in the air breathed has fallen to a point which appears to differ in different individuals.

Very similar conclusions have been formulated by Bergey, Weir, Mitchell, and Billings * as the result of their inquiry into "the composition of expired air and its effects upon animal life." They believe that the discomfort produced by crowded, ill-ventilated rooms in persons not accustomed to them is not due to the excess of carbon dioxide, nor to bacteria, nor, in most cases, to dusts of any kind. The two great causes of such discomfort, though not the only ones, are excessive temperature and unpleasant odours. These odours, which are perceptible to most persons on passing

* Bergey, Weir, Mitchell, and Billings: "The Composition of Expired Air and its Effect upon Animals," *Proc. Nat. Acad. of Sciences*, New York, 1895.

from the outer air into a crowded unventilated room, may be due in part to volatile products of decomposition contained in the expired air of persons having decayed teeth, foul mouths, or certain disorders of the digestive apparatus, and in part to volatile fatty acids produced from the excretions of the skin, and from clothing soiled with such excretions. The direct and indirect effects of odours of various kinds upon the comfort, and perhaps also upon the health, of men are probably more considerable than are indicated by any tests now known for determining the nature and quantity of the matters which give rise to them. Though the matter is one which still requires more elucidation, still the weight of evidence is greatly against the older view that the so-called organic matter of expired air possesses any toxic properties, but much in favour of the belief that it is the excessive presence of carbon dioxide and diminished amount of oxygen which renders air vitiated by respiration so hurtful.

DISEASES PRODUCED BY IMPURITIES IN AIR.

As possible and actual causes of diseased conditions, the impurities present in the air may be considered as to whether they exist (1) in the form of dust or particulate matter from fields, rooms, mines, or workshops; (2) in the form of gases or volatile effluvia arising from factories, drains, sewers, graveyards, or brickfields; (3) in the form of products of normal respiration and perspiration.

Effects of Dust and Particulate Matter.—The effect which is produced on the respiratory organs by substances inhaled into the lungs has long been known. Ramazzini and several other writers in the last century, and Thackrah more than fifty years ago in this country, directed special attention to this point, and since that time a great amount of evidence has accumulated, which shows that the effect of dust of different kinds in the air is a far more potent cause of respiratory diseases than is usually admitted. Affections of the digestive organs are also caused, but in a much slighter degree. The respiratory affections are frequently recurring catarrhs and bronchitis, with subsequent emphysema.

Acute pneumonia and especially chronic non-tubercular phthisis are also produced. The suspended matters in the air which may produce these affections may be mineral, vegetable, or animal; but it would seem that the severity of the effects is chiefly dependent on the amount of dust, and on the physical conditions as to angularity, roughness, or smoothness of the particles, and not on the nature of the substance, except in some special cases. A large number of the unhealthy trades are chiefly so from this cause. That summer catarrh or hay fever is produced in many persons by the pollen from grasses, trees, or flowers is now generally admitted. It is also known that the spores of certain fungi may cause skin diseases in men, and that some forms of *Tinea* and also *Favus* are thus sometimes spread seems certain. Again, that the infective matters of such diseases as scarlet fever, small-pox, measles, typhus, enteric fever, tuberculosis, pertussis, influenza, and others may in some cases reach the person through the medium of air, as well as by water or food, cannot be doubted. What is the precise degree of viability of various disease-producing bacteria in air we do not know, but we have considerable evidence to show that some pathogenic micro-organisms, notably those associated with small-pox, typhus, scarlet fever, erysipelas, and enteric fever are able to retain their virulency for some considerable time when exposed to the air and, under certain

favourable conditions, to be diffused by air currents over considerable areas.

The effects upon health of air which is rendered impure by mineral dust and dust from fabrics is clearly shown by the experiences of miners, flock-dressers, paper-makers, feather-dressers, shoddy-grinders, weavers, wire-grinders, masons, file-cutters, button-makers, and various other classes of artisans. The case of miners is particularly instructive.

Writing, in 1862, upon the conditions under which miners worked, Sir J. Simon states that the air of coal-mines, " besides being chemically insufficient for respiration, also carries with it into the miner's lungs more or less irritant material—material which, though the air were ever so well oxygenated, would itself tend to produce bronchitis—namely, soot, grit, and the acid fumes of combustion." He further goes on to show that at that time, with one exception, the miners in England as a class break down prematurely from bronchitis and pneumonia caused by the atmosphere in which they live and work. The one exception which he gives is the case of the Durham and Northumberland colliers, who, owing to the mines in those counties being exceptionally well ventilated, do not appear to suffer from an excess of pulmonary disease, or do so only slightly. Other writers show equally that, fifty years ago at any rate, the air of mines was bad, not only from respiratory vitiation, but from suspended matter, and its effect on the health of the miners was correspondingly bad.

In the present day, owing to sanitary legislation, the air of mines generally may be said to be fairly good. Ventilation is more or less efficiently carried out, particularly in the mines of the North of England, which are less dusty, and at the same time more readily ventilated than those of the Midland counties and of South Wales. Statistics show that phthisis, contrary to general opinion, is not an excessively common disease among miners.

The special decrease in diseases of the lungs among the South Staffordshire colliers, following improved ventilation of the mines, has been pointed out by Underhill; while Nasmyth, in a report upon the air of some Scotch coal-mines, considers that miners now have as good health, if not better, than above-ground labourers, at least so far as regards respiratory diseases. Arlidge, however, dissents from this opinion.

Although, thanks to the introduction of efficient ventilation, of shortened hours of labour, and to the increased attention given to the hygiene of mines, the general health of miners is better than it was a generation ago, still much dust is present in the air of even the best-managed mines, and the underground workers not only necessarily breathe large amounts of it, but suffer from its effects. The extreme fineness of coal dust diffused in pit workings is shown by its liability to take fire and cause explosions. This dust, when inspired, enters within the lung tissue, colours it both superficially and deeply in proportion to the amount and duration of its inhalation, and provokes subinflammatory lesions ending in fibrosis, and marked by symptoms of chronic bronchitis and by dyspnœa. Usually a considerable time elapses before the lungs take much notice of the foreign matter. When cough is established, expectoration follows.

The pathology of the morbid changes in these cases is that of a slowly generated fibrosis of the lung; it is not peculiar to coal-mining, but follows the continuous inhalation of other dusts besides that of coal.

In the pottery trade all classes of workmen are exposed to dust, especially, however, the flat-pressers. So common is emphysema that it is called " the potters' asthma."

So also among the china scourers; the light siliceous dust disengaged in great quantities is the cause of much disease.

The grinders of steel, especially of the finer tools, suffer perhaps the most of all from the effects of dust, though of late years the evil has been somewhat lessened by the introduction of wet-grinding in some cases, by the use of ventilated wheel-boxes, and by covering the work with linen covers when practicable. The wearing of masks and coverings for the mouth appears to be inconvenient, otherwise there is no doubt that a great amount of the dust might be stopped by very simple contrivances.

Button-makers, especially the makers of pearl buttons, also suffer from chronic bronchitis, and from the so-called fibroid phthisis. So also pin-pointers, some electro-plate workmen, and many other trades of the like kind, are more or less similarly affected.

In some of the textile manufactures much harm is done in the same way. In the carding-rooms of cotton, and wool, and silk spinners there is a great amount of dust and flue, and the daily grinding of the engines disengages also fine particles of steel. Since the cotton famine, a size composed in part of china clay has been much used in cotton mills, and the dust arising has produced injurious effects on the lungs of the weaver. In order to communicate the necessary amount of humidity, without which the warp thus sized with china clay could not be woven, of late years steam has been injected into the weaving-sheds, so that the weavers, instead of breathing in dust, fill their lungs with moisture, and work all day in damp clothes, becoming very liable to bronchitis, &c., on leaving the over-heated factory.

In flax factories a very irritating dust is produced in the process of hackling, carding, line-preparing, and tow-spinning. In shoddy factories, also, the same thing occurs. These evils appear to be entirely and easily preventable. In some kinds of glass-making, also, the workmen suffer from floating particles of sand and felspar, and sometimes potash or soda salts.

The makers of grinding-stones suffer in the same way; and children working in the making of sand-paper are seriously affected, sometimes in a very short time, by the inhalation of fine particles of silica into the lungs.

In making Portland cement, the burnt masses of cement are ground down, and then the powder is shovelled into sacks; the workmen doing this cough a great deal, and often expectorate little masses of cement. Some of them have stated that if they had to do the same work every day it would be impossible to continue it on account of the lung affection. Sir Charles Cameron has called attention to the fatal effects of vapours of silicon fluoride in making superphosphate; it forms a gelatinous deposit on the mucous membrane of the air-passages, and causes death by suffocation.

The makers of matches, who were exposed to the fumes of phosphorus, suffered formerly from necrosis of the jaw, if there were any exposed part on which the fumes could act. This, however, is now obviated by the use of amorphous or red phosphorus, which is harmless.

In making bichromate of potash, the heat and vapour employed carry up fine particles, which lodge in the nose and cause great irritation, and finally ulceration, and destruction of both mucous membrane and bone. Those who take snuff escape this. The mouth is not affected, as the fluids dissolve and get rid of the salt. The skin is also irritated if the salt is rubbed on it, and fistulous sores are apt to be produced. No effect is noticed to be produced on the lungs.

In some trades, or under special circumstances, the fumes of metals, or particles of metallic compounds, pass into the air. Brassfounders suffer

from bronchitis and asthma as in other trades in which dust is inhaled; but in addition they also suffer from the disease described as "brassfounders' ague." It has been thought to have been produced by the inhalation of fumes of zinc oxide; the symptoms are tightness and oppression of the chest, with indefinite nervous sensations, followed by shivering, an indistinct hot stage, and profuse sweating. These attacks are not periodical. They are probably due to an admixture of zinc and copper poisoning.

Coppersmiths are affected somewhat in the same way, by the fumes arising from the partly volatilised metal, or from the spelter (solder).

Tinplate workers also suffer occasionally from the fumes of the soldering.

Plumbers, also, are now and then affected by the fumes of solder, of which lead is a principal ingredient, as well as by handling the metal itself. Nausea and tightness of the chest are the first symptoms, and then colic and palsy.

Manufacturers of white lead inhale the dust chiefly during the handling of the jars containing the converted metal—the carbonate—and during the process of crushing. Its subsequent grinding is done wet. House-painters also inhale the dust of white lead to a certain extent, though in these, as in former cases, much lead is swallowed from want of cleanliness of the hands in taking food.

Workers in mercury, silverers of mirrors, and water-gilders (men who coat metal with an amalgam of mercury and gold) are subject to mercurialismus. Electricity has rendered gilding with the aid of mercury to some extent obsolete; while modern invention has replaced the older method of silvering mirrors by one largely devoid of its evils, namely, by precipitating metallic silver upon the surface of the glass from a tartrate of the metal.

Workmen, who use arsenical compounds, either in the making of wall-papers or of artificial flowers, &c., suffer from slight symptoms of arsenical poisoning, and many persons who have inhaled the dust of rooms papered with arsenical papers have suffered from both local and constitutional effects. Arsenic has been detected in the urine of such persons.

Effects of Gases and Volatile Effluvia.—The evidence regarding the influence of gases and other emanations upon health is both indefinite and discursive. It will, however, be most conveniently considered in the following manner:—

Ammoniacal Vapours.—An irritating effect on the conjunctiva seems to be the most marked effect of the presence of these vapours. There is no evidence showing any other effect on the health.

Hydrochloric Acid Vapours in large quantities are very irritating to the lungs; when poured out into the air, as was formerly the case in the alkali manufactures, they are so diluted as apparently to produce no effect on men, but they completely destroy vegetation. In some processes for making steel, hydrochloric, sulphurous and nitrous acids, and chlorine are all given out, and cause bronchitis, pneumonia, and destruction of lung tissue, as well as eye diseases.

Carbon Disulphide.—In certain processes in the manufacture of vulcanised india-rubber a noxious gas is given off, supposed to be the vapour of carbon disulphide. It produces headache, giddiness, pains in the limbs, formication, sleeplessness, nervous depression, and complete loss of appetite. Sometimes there is deafness, dyspnœa, cough, febrile attacks, and even amaurosis and paraplegia. The effects seem due to a direct anæsthetic effect on the nervous tissue.

Carburetted Hydrogen.—A large quantity of carburetted hydrogen can be breathed for a short time—as much, perhaps, as 200 to 300 volumes per

1000. Above this amount it produces symptoms of poisoning, headache, vomiting, convulsions, stertor, dilated pupil, &c. Breathed in small quantities, as it constantly is by some miners, it has not been shown to produce any bad effects; but there, as in so many other cases, it is to be wished that a more careful examination of the point were made. Without producing any marked disease, it may yet act injuriously on the health.

Carbon Monoxide.—Of the immense effect of carbon monoxide there is no doubt. The red colouring-matter of the blood forms with the carbonic oxide a much more stable compound than it does with oxygen, and, consequently, in the presence of the gas, the oxygen of the blood gradually becomes replaced by carbon monoxide. If too little of the oxygen compound is formed to support life, death ensues. Air containing 0·4 per cent. of carbonic oxide may in one hour prove fatal to a person asleep. The compound formed by the colouring-matter of the blood with carbon monoxide is of a cherry-red colour, and, usually, when death has resulted from its inhalation, the pink colour of the lips, of the nails, and of any other part of the body where the colour of the blood can be seen through the skin is sufficiently indicative of the cause. A very rapid parenchymatous degeneration takes place in the heart and muscles generally, and in the liver, spleen, and kidneys.

If, on the other hand, fresh air is admitted to the lungs before death occurs, the carbon monoxide is gradually eliminated from the blood. The eliminating force is the affinity of oxygen for the colouring-matter, and, since the one gas tends to drive the other out, the higher the percentage of oxygen in the air breathed, the quicker will the elimination of the carbonic oxide be.

The use of "water gas" by municipalities and gas companies has added much to the danger from carbon monoxide poisoning. In many towns in England carburetted water gas is distributed to consumers mixed with ordinary coal gas. The particular danger associated with water gas, Dowson gas, &c., is that of poisoning by carbon monoxide. In carburetted water gas it reaches 30 per cent., and in the uncarburetted water gas amounts to nearly 50 per cent. Dowson gas usually contains 25 per cent. Fatal poisoning in factories has resulted from the cleaning out Dowson tanks before a sufficient time had been allowed for the gas to escape, from repairing faulty connections in pipes containing the gas, and from gradual escape of the gas through faulty valves of a gas-engine. Carbon monoxide is also found in lime-kilns, and where braziers and coke fires are used in confined spaces.

Hydrogen Sulphide.—The evidence with regard to this gas is contradictory. While dogs and horses are affected by comparatively small quantities, and suffer from purging and rapid prostration, men can breathe a larger amount. When inhaled in small quantities, and continuously, it has appeared in some cases harmless, in others hurtful. Thackrah, in his inquiries, could trace no bad effects. Hirt, on the other hand, has no doubt of the occurrence of chronic poisoning among men who work among large quantities of the gas. The symptoms are chiefly weakness, depression, anorexia, slow pulse, furred tongue, and marked pallor. Sometimes there is a furunculoid eruption on different parts of the body. In some cases there are vertigo, headache, nausea, diarrhœa, emaciation, and head symptoms. He notices differences of susceptibility, which is also sometimes increased with custom.

Roburite, a mixture of di-nitro-benzene, chloro-nitro-benzene, and ammonium nitrate, has lately been used as an explosive in coal-mines, as it has the advantage of not producing any flame such as might ignite coal

dust, or any inflammable gas in the mine. Miners making use of this compound have been found to suffer from pains in the head and stomach, difficulty of breathing on exertion, and loss of muscular power; with, in severe cases, blueness of lips, high-coloured urine and loss of consciousness. These symptoms may be acute or chronic; they are characteristic of nitro-benzene poisoning. Other persons, not handling the roburite, but exposed to its fumes, have been known to suffer from headache, tightness across the forehead, loss of muscular power, drowsiness, and occasionally vertigo, followed by vomiting. Carbon monoxide is produced by its explosion, and every care should be taken to remove the fumes by thorough ventilation.

Somewhat similar symptoms, but especially marked cyanosis, have been noted in connection with the manufacture of the "Sicherheit explosive."

Nitro-benzol, formed by the action of nitric acid upon benzol and used in some manufactures, is closely allied to the foregoing. Long exposure to its vapour produces stupor; if the vapour is inhaled in a concentrated form, the drowsiness passes in a short time into complete coma. The mind remains clear until the stupor suddenly comes on, when the insensibility is usually complete. Death frequently ensues in a few hours. Letheby, who had considerable experience of these fumes, attributed the symptoms which they produced to the conversion within the body of nitro-benzol into aniline, but this view has not been confirmed by experimental facts.

Myrbane is a form of nitro-benzol, having only slightly poisonous properties, unless taken or inhaled in large amount. Owing to its bitter-almond odour and taste, it is used as a scent for soaps and pomades, also to give flavour to sweetmeats.

A table (from Lehmann) is given below, which shows the concentrations at which some important industrial gases occasion injury to health.

	Concentrations which rapidly cause dangerous injury.	Concentrations bearable for 30 to 60 minutes without grave effects.	Concentrations which occasion only trifling symptoms after an action of some hours.	Authorities.
Hydrochloric acid	1·5 to 2 per 1000	0·05 to 0·1 per 1000	0·01 per 1000	Matt, Dissertation Wurzburg, 1889.
Sulphur dioxide	0·5 per 1000	0·05 or less per 1000		Ogata, *Archiv. f. Hyg.*, iii.
Carbon dioxide	About 30 per cent.	6 to 8 per cent.	1 to 2 per cent.	Emmerich and Herter, *Zeit. f. Phys. Chemie*, ii.
Ammonia	2·5 to 4·5 per 1000	0·3 per 1000	0·1 per 1000	Matt, *loc. cit.*
Chlorine and Bromine	0·04 per 1000	0·004 per 1000	0·001 per 1000	Matt, *loc. cit.*
Iodine		0·003 per 1000	0·005 per 1000	Matt, *loc. cit.*
Hydrogen sulphide	0·5 per 1000	0·2 per 1000	0·1 per 1000	Lehmann, *Zeit. f. Hyg.*, xiv.
Carbon di-sulphide	0·01 per 1000	0·002 per 1000	0·001 per 1000	Lehmann, *Bericht der Bay. Akad.*, Mar. 3, 1888; also *Arch. f. Hyg.*, xv.
Carbon monoxide	2–3 per 1000	0·5 to 1 per 1000	0·2 per 1000	Max Gruber, *Arch. f. Hyg.*, ii.

Sulphur Dioxide.—The bleachers in cotton and worsted manufactories, and storers of woollen articles, are exposed to this gas, the amount of which

in the atmosphere is, however, unknown. The men suffer from bronchitis, and are frequently sallow and anæmic.

When sulphur dioxide is evolved in the open air, and therefore at once largely diluted, as in copper smelting, it does not appear to produce any bad effects in men, and indeed persons living in volcanic countries have sometimes a notion that the fumes of this gas are good for the health; de Chaumont was told so by the people in the neighbourhood of Vesuvius. When, however, it is washed down with rain, it affects herbage, and, through the herbage, cattle; it is then said to cause affections of the bones, falling off of the hair, and emaciation.

Effects of Effluvia from Brickfields and Cement Works.—The fumes from burning bricks differ in composition according as to whether they are burnt in kilns or clamps. In kiln burning, the bricks are burnt by the aid of coal, no combustible material being mixed with the bricks. In clamp burning, the green bricks are mixed with a small proportion of ashes or other *débris*, and then arranged in layers alternating with breeze, so as to form a quadrangular pile. The breeze is set alight by means of small wood and coal fires. Clamp burning is distinctly offensive, as, in addition to the ordinary gases of combustion, certain pyroligneous matters are emitted which have an intensely disagreeable odour; these objectionable effects mainly result from the use of household refuse in the construction of the clamps. The effluvia from brick clamps and kilns are usually acid, irritating and injurious to vegetation. Clamp burning should not be permitted in populous neighbourhoods. Kiln burning, if carried out in well-constructed kilns provided with a long chimney-shaft, can be conducted with but little offence.

The manufacture of the so-called Roman cement, made from the *septaria* nodules found in the London clay, creates little nuisance, as the stones are calcined in open kilns like lime-kilns. The manufacture of Portland cement is less satisfactory. This cement is made from a mixture composed of chalk and clay, and the chief nuisance arises during the burning of this mixture, whereby large quantities of carbon dioxide, carbon monoxide, hydrogen sulphide, and volatile cyanides are emitted. The evolution of cyanides is particularly intense when the clay used contains much nitrogenous matter. Experience shows that the emanations from open kilns in the manufacture of Portland cement are clearly injurious to health. The fumes should always be discharged from a tall chimney, not less than 150 feet high.

Effects of Effluvia from Offensive Trades.—The chief industries in which offensive effluvia are generated are:—Pig-, horse-, and cow-keeping, tanning and leather-dressing, glue- or size-making, fell-mongering, the manufacture of oxalic acid, paper and wood pulp, also the making of sal-ammoniac and coal gas, the distillation of tar and of palm oil, also the manufacture of carbolic acid, alkali, salt, sulphuric acid, picric acid, and the various aniline dyes.

In the majority of these trades large quantities of very disagreeable vapours are constantly produced, which often spread for long distances, and are at the same time most offensive. In the case of businesses involving the keeping of animals, impregnation of the atmosphere with ammonia is the chief offence. In tanning and leather-dressing, glue- or size-making, and fell-mongering, ammonia and other products of the decomposition of animal matters generally are objectionably obvious. From india-rubber factories the chief smell is a peculiar india-rubber odour, together with an odour of tar oil and sulphuretted hydrogen. The making of oxalic acid

from sawdust entails the evolution of very acid and irritating fumes; similarly, in the making of paper and wood pulp, a peculiar and offensive odour of an indefinite nature is a constant feature. The presence of alkaline sulphide vapours is the chief objection to the making of sal-ammoniac, coal gas, carbolic acid, and the distillation of tar. The extremely irritating acrolein vapours are the product of linoleum factories, and distilleries of palm oil, "foots," and other kinds of grease. From alkali works, the acid fumes produced are sulphuric acid, sulphurous acid, nitric acid, various other noxious oxides of nitrogen, sulphuretted hydrogen and chlorine. In the case of the making of sulphuric acid, the chief effluvia are caused by the escape of sulphurous acid and the higher oxides of nitrogen; while fumes of hydrochloric and sulphurous acids largely result from the manufacture of salt, and the heavy odour of essence of myrbane with nitrous acid is the chief effluvium from the making of picric acid and the aniline colours.

Although these industrial gases frequently constitute a nuisance, it is difficult in the greater number of instances to bring forward any positive evidence of insalubrity. The odours, however, in most cases are so bad that rules have to be enforced to secure the conveyance in covered carts or receptacles of all offensive matters in or about the business premises. Similarly, in order to prevent nuisance from the vapours given off in boiling processes, all such operations need to be conducted in closed vessels each having a pipe to lead the steam into a furnace flue. In other cases, the arrest of offensive gases is secured by condensation in a special apparatus, or their absorption is effected by lime and other chemical means.

Effects of Effluvia from Sewers and House Drains.—Cases of asphyxia from hydrogen sulphide, ammonium sulphide, carbon dioxide, and nitrogen (or possibly rapid poisoning from organic vapours), occasionally occur both in sewers and from the opening of old cesspools. When the air of sewers penetrates into houses, and especially into bedrooms, it certainly causes a greatly impaired state of heath, especially in children. They lose appetite, become pale and languid, and suffer from diarrhœa; older persons suffer from headaches, malaise, and feverishness; there is often some degree of anæmia, and it is clear that the process of aeration of the blood is not perfectly carried on.

In some cases decided febrile attacks, lasting three or four days and attended with great headache and anorexia, have been known. Houses into which there has been a continued escape of sewer air have been so notoriously unhealthy that no persons would live in them, and this has not been only from the prevalence of fever, but from other diseases.

The effect on the men who work in sewers which are not blocked, or temporarily impure from exceptional disengagement of hydrogen sulphide from any cause, has been subject to much debate. The air in many sewers in London is not very impure; the analyses have shown that generally the amount of carbon dioxide is very little in excess of that in the external air, and that there is hardly a trace of hydrogen sulphide or of fœtid organic effluvia. The air in the house drains is often, in fact, more impure than that of the main sewers. This is the case also in other places, and is to be accounted for by the numerous openings in the sewers, by the porosity of the walls, by the continual ventilation produced by the air being drawn into houses, and by the amount of water in the sewers being often so great, and its flow so rapid, as to materially lessen deposits and other sources of generation of gas. The evidence is, on the whole, opposed to the view that sewer-men suffer in health in consequence of their occupation.

The air of sewers passing into houses aggravates most decidedly the

severity of the exanthemata, more especially such diseases as erysipelas, hospital gangrene, and puerperal fever; it has probably an injurious effect on all diseases. That pneumonia may be connected with effluvia from sewers and house drains was shown in the epidemic at Middlesborough, where Ballard found good reason for attributing considerable influence to defective drainage as an agency in the incidence of the disease.

Two diseases in particular have been supposed to arise from the air of sewers and fæcal emanations, viz., *enteric fever*, and *diphtheria*.

That enteric fever may arise from the effluvia from sewers is a popular belief in this country, but is supported by imperfect evidence. There are several cases on record in which this fever has constantly prevailed in houses exposed to sewage emanations, either from faulty drains or from want of sewers, and in which proper sewerage has completely removed the fever. Many of these occurred before the water-carriage of enteric fever was recognised, and it is open to argument whether the amelioration in health, which followed the introduction of well-constructed sewers and drains in these cases, was not due to the removal of sources of pollution to local water-supplies rather than to the removal of facilities for the entrance of sewer air and gas into the houses.

In other cases where stress has been laid upon the influence of sewer air and sewer gases escaping into dwellings as the probable cause of subsequent cases of enteric fever occurring therein, it has been frequently overlooked that concurrent circumstances often were an intermittent water-supply, and infection of the drinking water by specifically tainted matter sucked up into cisterns or pipes from the trapping bends of faultily planned and constructed drains. The well-known outbreak of enteric fever at Caius College, Cambridge, investigated by the late Sir G. Buchanan, was traced by him to a similar cause. In this case, the entrance of excretal matter into the water-supply was an etiological factor of greater importance than the escape of sewer gas or air into the building.

The spread of *diphtheria* has been ascribed to the pollution of air by emanations from sewers, and certainly in many outbreaks there has been a connection between the sanitary condition of a district and the incidence of the disease; houses or groups of houses to which sewer gas has gained access through faulty traps having especially suffered.

Direct proof of such a causal connection has not yet been afforded, and it must be admitted that diphtheria has up to comparatively recent years been a disease of country districts rather than of regularly sewered towns; at the same time, if the sewerage arrangements are defective, allowing the escape of sewer air into dwellings, especially sleeping-rooms, it is *à priori* probable that the sewer gases, by giving rise to a relaxed and unhealthy condition of the mucous lining of the throat, may increase the liability to attack by diphtheria in the event of exposure to specific infection.

Although it seems difficult not to admit that the effluvia from sewers and drains may predispose towards the incidence of enteric fever, there are yet some remarkable facts which can be cited on the other side. Thus it has been repeatedly denied that enteric fever is more common among sewer-men than others, and later inquiries among the sewer-men of London seem to bear out the assertion. The possibility that the adult persons submitted to sewage emanations may have had enteric fever in early life, and are, therefore, insusceptible, may explain some cases of escape, even when fæcal emanations are constantly breathed.

In spite of its apparent bacterial innocuousness, no one entertains the least doubt that sewer air is a constant source of ill-health, and though it

may not directly act, yet so prepares the soil that the system is unable to resist the invading organism when it comes. Recent experiments * show that specific bacteria present in sewage may be ejected into the air of ventilation pipes, inspection chambers, drains, and sewers by the bursting of bubbles at the surface of sewage, by the separation of dried particles from the walls of pipes, chambers, and sewers, and probably by the ejection of minute droplets from flowing sewage.

Effects of Emanations from Fæcal Matter thrown on the Ground.—Owing, doubtless, to the rapid movement of the air, there is no doubt that the excreta of men and animals thrown on the ground and exposed to the open air are less hurtful than sewer air, and probably in proportion to the dilution.

When there are accumulations in close courts, small back-yards, &c., the same effects are produced as by sewer air. When fæcal matters are used for manure, and are therefore speedily mixed with earth, they seldom produce bad effects. Owing, doubtless, to the great deodorising and absorbing powers of earth, effluvia soon cease to be given off. The history of most sewage farms in this country certainly supports the view that no harm accrues to the neighbourhood as the result of pouring fæculent material on land. The remarkable immunity from harm which has followed the direct return of human excrement to the superficial soil layers is probably due, so far as this country is concerned, to the average humidity of the soil and air, conditions which do not favour ready dispersion by air currents. It is probably otherwise in tropical or arid countries ; certainly in India there prevails a strong opinion that not a little of the prevalent enteric is due to the local custom of disposing of sewage by superficial burial. This practice in dry seasons favours the dissemination of fæcally laden dust which fouls air, water, and food. From our own experiences in tropical countries we are disposed to admit the legitimacy of this view, and to lay stress upon the absolute need of moisture to fix the noxious material in the soil and so minimise the possibilities of any transference of micro-organisms or other particulate matter from the soil to the air.

Effect of Manure Manufactories.—The manure manufactories at present existing in this country do not appear to produce any bad effects. They are generally at some little distance from towns, and the effluvia are soon diluted. But if situated in towns they are nuisances, and may be hurtful.

In France the workmen engaged in the making of "poudrette" do not in any way suffer, except from slight ophthalmia. When the poudrette is decomposing, and large quantities are brought into small spaces, as on board ship, serious consequences may certainly result, the chief symptoms produced being intense pain in the head and limbs, with vomiting, great prostration, and diarrhœa. In bone manure factories it has been shown that arsenic is given off in the fumes in considerable quantity, arising from the use of impure sulphuric acid.

Effects of Air vitiated by Respiration.—If we disregard the presence, in expired air, of the so-called and more or less hypothetical organic matter, the chief causes of discomfort, following the use of air vitiated by respiration, are the deficiency of oxygen, excess of carbon dioxide, and increased heat and moisture. The influence of a deprivation of oxygen, in producing a condition of hyperpnœa, appears to be largely

* Horrocks: "Experiments to Determine the Conditions under which Specific Bacteria derived from Sewage may be present in the Air of Drains and Sewers," *Journal Royal Sanitary Institute*, vol. xxviii. p. 176.

subordinate to that of an excessive presence of carbon dioxide. The normal quantity of this latter gas, in air, being from 0·3 to 0·4 volume per 1000, fatal results are produced when the amount reaches from 50 to 100 per 1000 volumes; while at an amount much below this, say 15 to 20 per 1000, it produces, in some persons at any rate, severe headache. Some persons can inhale, for a brief period, considerable quantities of carbon dioxide without injury; and animals can be kept for a long time in an atmosphere highly charged with it, provided the amount of oxygen be also increased. Headache and vertigo are produced when the amount of carbon dioxide in the air of respiration is not more than 1·5 to 3 volumes her 1000. Well-sinkers, when not actually disabled from continuing their work by carbon dioxide, are often affected by headache, sickness, and loss of appetite; but the amount of carbonic acid has never been actually determined in these cases.

The effect of constantly breathing an atmosphere containing an excess of carbon dioxide is not yet perfectly known. Angus Smith attempted to determine its effect *per se*, the influence of the so-called organic matter of respiration being eliminated. He found that 30 volumes per 1000 caused great feebleness of the circulation, with, usually, slowness of the heart's action; the respirations were, on the contrary, quickened. These effects lessened when the amount was smaller, but were perceptible when the amount was as low as 1 volume per 1000—an amount often exceeded in dwelling-rooms. At the same time, this is not the case always, for in mineral water factories, where the carbon dioxide often amounts to as much as 3 per 1000, no discomfort is experienced.

The importance of the *rôle* played by the heat and capacity for moisture of air vitiated by respiration is often overlooked. We have already seen that expired air is practically of the same temperature as the body, and saturated with water vapour, consequently any volume of air much vitiated by respiration soon becomes heated and more or less saturated with moisture. Now air which is loaded with moisture transmits, in each unit of time, much more heat than air which is dry. Hence, when air, at a high temperature, is saturated with watery vapour, it communicates heat to the body, producing an oppressive sensation; but when the temperature of the saturated air is lower than the temperature of the body, the transfer of heat is the other way, producing a sensation of cold. A low temperature with a dry atmosphere is therefore more comfortable than a higher temperature when the air is loaded with moisture, because the former favours the prompt and regular removal of body heat by combined conduction and evaporation. It is precisely in this quality that air, vitiated by respiration, is so wanting, with the result that it causes a sense of unpleasant oppression so characteristic of ill-ventilated and over-crowded rooms.

The effect of air much fouled by respiration is very marked upon many people, producing heaviness, headache, inertness, and in some cases nausea. When air has been rendered very impure, it is commonly rapidly fatal, as in the cases of the Black Hole at Calcutta, of the prison in which 300 Austrian prisoners were put after the battle of Austerlitz (when 260 died very rapidly), and of the steamer *Londonderry*. This vessel left Sligo for Liverpool on December 2, 1848, and stormy weather coming on, the captain forced 200 steerage passengers into their cabin, which measured 18 feet by 11 feet, and 7 feet in height. The hatches were battened down and covered with tarpaulin. When the cabin was opened 72 persons were found dead, and several expiring.

The poisonous agencies which probably bring about this sequence of

events appear to be a deficiency of oxygen coupled with an excess of carbon dioxide, though the symptoms are not those of pure asphyxia. If the persons survive, a febrile condition is usually left behind, which lasts three or four days, followed often by boils and other evidences of affected nutrition.

When air more moderately vitiated by respiration is breathed for a longer period, and more continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is at the same time sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health. Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits. The aeration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears clear that pulmonary affections are more common.

Those breathing vitiated air appear to furnish a most undue percentage of phthisical cases, that is, of destructive lung-tissue disease of some kind. The production of phthisis from impure air (aided most potently, as it often is, by coincident conditions of want of exercise, want of good food, and excessive work) is no new doctrine. Carnelley, Haldane, and Anderson show that in Dundee the ratio of phthisis and other disorders of a similar character increases with the crowding and foulness of the air; being at the rate of 3·26 per 1000 in houses of four rooms and upwards; 5·52 in houses of three rooms; in two-roomed houses, 6·41; and in one-roomed houses, 7·44. In prisons, the great mortality which formerly occurred, as, for example, at Millbank, seemed to be owing to bad air, conjoined with inferior diet and moral depression.

The now well-known fact of the great prevalence of phthisis in most of the European armies during former years can scarcely be accounted for in any other way than by supposing the vitiated atmosphere of the barrack-room to have been chiefly in fault. This is the conclusion to which the Sanitary Commissioners for the Army came in their well-known report. Certainly, recent improvements in barrack construction, lessening of overcrowding and better ventilation have resulted in less disease, particularly tuberculosis, among soldiers. The story is the same from the Navy; formerly the incidence of phthisis among sailors was enormous, attributable entirely to the faulty ventilation of ships and to contagion following on this. It is true that even on modern battleships the purity of the air between decks is far from satisfactory, and the incidence of pulmonary affections among sailors and marines somewhat high, but as compared with former years the present conditions are fairly good.

The remarkable incidence of tuberculosis and other respiratory diseases among animals in confinement is another striking instance of the evil effects of overcrowding and the constant breathing of an atmosphere contaminated by respiration.

EXAMINATION OF AIR.

For hygienic purposes, in the practical examination of air, the chief points to which attention needs to be directed are, the collection of the sample, the examination of the air by the senses, estimation of oxygen, estimation of carbon dioxide, determination of the oxidisable and organic matter, estimation of carbon monoxide, the presence of ozone, the deter-

mination of aqueous vapour, and an examination of the suspended matter and micro-organisms.

Collection of the Sample.—All air samples should be collected at the time when the atmosphere will afford its greatest evidence of pollution, as, for instance, in the case of a bedroom, the air should be taken when its usual occupants have been in it some hours. For the actual collection of the sample, large, wide-mouthed, glass-stoppered jars, holding from 3 to 4 litres, are the most convenient. These need to be most thoroughly cleansed with distilled water before use, inverted to run dry, and stoppered, a label being finally attached for stating the current temperature and pressure. To fill the jar with the air sample, either of the two following methods may be employed:—

1. The air may be blown in by bellows which are provided with a long nozzle capable of reaching to within an inch of the bottom of the jar; this ensures that the air which originally filled the jar will be entirely displaced from below upwards.

2. The jar may be accurately filled with distilled water, then inverted, emptied and allowed to drain dry in the room, the air of which it is desired to collect; as the water flows out, some of the air rushes in to fill its place. Special care needs to be observed that no breath is introduced into the jar. The vessel is at once closed with an air-tight stopper or india-rubber cap, and the label inscribed with the current temperature, barometric pressure, and cubical capacity of the jar.

Examination by the Senses.—From a practical point of view this is of the first importance, as although carbon dioxide, carbon monoxide, marsh gas, and several other vapours cannot be detected by the smell, still minute quantities of organic effluvia, traces of sulphuretted hydrogen, of coal gas, of carbon disulphide, and of various other substances are readily noticed by the sense of smell, particularly if at all trained or cultivated to acuteness. The special value of the sense of smell in recognising the peculiar fœtid odour so characteristic of occupied rooms was first clearly shown by de Chaumont, who further indicated the importance of observing it on first entering a room from the open air. He also pointed out the marked influence which atmospheric humidity has in rendering the smell of organic matter perceptible, an increase of 1 per cent. in the humidity being as powerful, in this respect, as a rise of 2°·32 C. (4°·18 F.). As the sense of smell soon becomes blunted, it is important, when attempting any examination of the air by the senses, to record the impression received immediately after entering the suspected or vitiated air from the open, and not to delay it until one has been in the apartment some length of time. These points have been emphasised recently by Gordon * who adduces remarkable evidence to show how very far normal sense of smell exceeds in acuteness any other means at present used to demonstrate the presence of minute particulate matter.

Estimation of Oxygen.—For this determination there are three well-known methods, namely, the pyrogallic acid process, the combustion process with excess of hydrogen, and the nitric oxide method. As neither of the first two are strictly available in presence of carbon dioxide, the third procedure is the one most readily applicable for hygienic estimations.

The most convenient apparatus is Hempel's gas burette and absorption pipette. It consists of two upright glass tubes, one of which is graduated into cubic centimetres, and the other plain. The graduated tube is narrowed almost to capillarity at the top, and drawn out so as to take an india-rubber connecting-tube. Both tubes are fitted into stands at the bottom and

* Gordon: Report on the Ventilation of the Houses of Parliament, London, 1905.

connected with each other by a wide rubber tube. The graduated upright burette is designed for the reception and measurement of the air or gas. The plain upright burette is the pressure-tube, its function being to regulate the pressure in the other tube (*see* Fig. 6).

In order to use the burette, water must first be introduced, so as to rather more than half fill it. By raising the pressure-tube, the water will be caused to fill the graduated tube. By lowering the pressure-tube, a sample of air may thus be drawn into the graduated tube, which is left open at its upper end. So soon as air has been drawn into the graduated tube, a pinch-cock is made to close the upper connecting rubber tube, thereby confining the air sample in the graduated burette.

The next operation is to read off the volume of air. For this purpose it must be placed under the current barometric pressure by raising or lowering the pressure-tube until the level of the water is the same in both tubes. If the graduated tube be now read off, the volume of air in it can be expressed in c.c. Having been measured, the air sample is submitted to certain reactions in what is called an absorption pipette. By a reference to the figure, this will be seen to consist of four glass bulbs, one having a larger diameter than the others, and capable of holding at least 150 c.c. of the reagent to be employed, while the others should have a capacity of at least 100 c.c. By means of india-rubber connecting tubes and bent capillary glass tubes, the gas burette is placed in communication with the absorption pipette. The india-rubber connections should be bound with thin copper wire, and the respective tubes provided with pinch-cocks; these latter need to be carefully closed before any manipulation of the connections takes place.

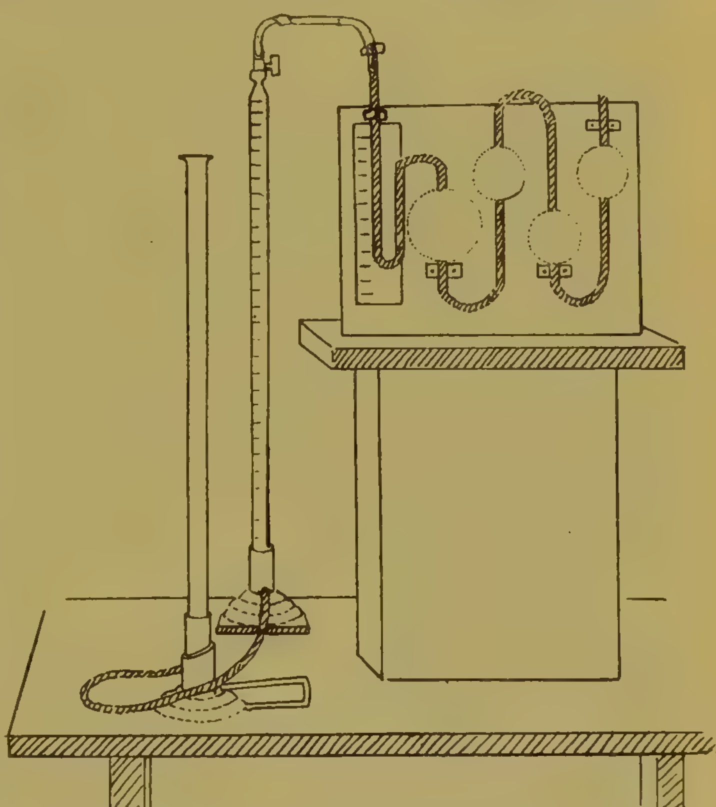


Fig. 6.

Apparatus for Estimation of Oxygen in Air.

The particular method for estimating oxygen is based upon the well-known reaction between oxygen and nitric oxide, thus, $2NO + O_2 = 2NO_2$. The NO_2 is absorbed by water; there is, therefore, a contraction of three volumes for every one volume of oxygen. The mode of operation is to add excess of nitric oxide to the sample of air, and then to read the contraction. One-third of the contraction is the volume of the oxygen in the sample.

Some nitric oxide is prepared by the action of dilute nitric acid on copper turnings, the gas being preserved in a bell jar over water. The absorption pipette is next charged with water, and a sample of air having been drawn into and measured in the gas burette is then, after connecting the burette

with the pipette, passed over into the absorption pipette and there allowed to remain while nitric oxide is introduced into the gas burette and its volume measured. This being done, the nitric oxide is passed over to the air in the absorption pipette. Immediately the well-known reaction takes place, and ruddy fumes of NO_2 make their appearance in the bulb of the absorption pipette. The absorption of these fumes by the water is very quick. The gas is passed backwards and forwards once or twice, the fumes disappear, and the final reading at once made.

Example.—Say 50 c.c. of air are drawn into the gas burette and duly passed over, after connection, into the absorption pipette containing water. Say, further, that 25 c.c. of NO_2 are drawn in, measured, and also passed over into the air in the absorption pipette. After the reaction has taken place and is completed, presume the resulting volume of air is found to be 44·2 c.c.; that is, 50+25 or 75 c.c. has become 44·2 c.c., being a contraction of 30·8 c.c.: one-third of this contraction, or 10·27 c.c., is the volume of oxygen present in the air sample of 50 c.c.; or, in other words, 20·54 per cent.

In this, and all other processes of gas analysis, since the conditions of temperature should remain constant throughout the estimation, it is of importance that the gas burette, after it has been charged, should not be handled except by its iron stand.

Estimation of Carbon Dioxide.—The determination of this gas in air is of the greatest general importance, mainly because, as a product of both respiration and combustion, it affords an important index as to the extent to which other impurities co-exist. The procedure for its estimation in most common use is Pettenkofer's alkalimetric method.

The rationale of the process is as follows:—Clear lime-water or baryta-water, both being strongly alkaline media, will readily absorb carbon dioxide; the absorption of this weak acid will diminish the alkalinity or causticity of the original lime- or baryta-water. If, therefore, the degree of alkalinity of either of these media be known both before and after exposure to the carbon dioxide, the difference will represent the amount of CO_2 which has combined with the lime or baryta.

To carry out the process it is necessary to have a clean glass vessel capable of holding about a gallon or 4·5 litres. The capacity of this jar is determined by filling it with water at 15° C. (=59° F.), and measuring the contents by means of a litre or pint measure, one fluid ounce equalling 28·4 c.c. As already explained, the most convenient way of collecting the air sample is to fill the jar with water and empty it in the place the air of which is to be examined, and then allowing it to drain for awhile. When this has been done, 60 c.c. of clear lime- or baryta-water are put in, and the mouth of the jar closed with an india-rubber cap. The vessel is agitated, so that the lime- or baryta-water may run over the sides and thus become intimately exposed to the action of the air contained in the vessel. The same is then allowed to stand for half an hour or longer.

The causticity of the lime- or baryta-water is next determined by titration with a solution of crystallised oxalic acid, made by dissolving 2·25 grammes of the acid in a litre of distilled water. One c.c. of this solution exactly neutralises 1 milligramme of lime, CaO, or 2·73 milligrammes of baryta, BaO. For the actual determination of causticity, 30 c.c. of the lime- or baryta-water are taken and exactly neutralised with the oxalic acid solution, good turmeric paper, or rosalic acid or phenol-phthalein being used as indicators. If rosalic acid be used, a few drops of a solution made by dissolving 0·5 gramme of rosalic acid in 100 c.c. of 80 per cent. alcohol may be added to the lime- or baryta-water. If phenol-phthalein be employed, a suitable solution is made by dissolving 5 grammes of the phenol-phthalein, with the aid of 25 c.c. spirits of wine, in 500 c.c. of distilled water. The amount of

lime in the 30 c.c. taken will be then equal to the number of c.c. of the oxalic acid used; it is usually somewhere between 34 and 41 milligrammes. In the case of baryta the amount in the 30 c.c. will be 2·73 times the number of c.c. of the oxalic acid used.

In the same manner, after the lime or baryta placed in the jar has absorbed the CO_2 of the air in the vessel, 30 c.c. of it are taken out and tested for causticity with the oxalic acid, the difference between this and the previous determination showing the milligrammes of lime or baryta precipitated or combined with the carbon dioxide.

Before proceeding further with the calculation, it is necessary to estimate, subject to corrections for temperature and barometric pressure, the volume of air contained in the jar, reducing the same to normal conditions of 0° C. and 760 mm. This reduction to normal conditions of temperature and pressure is necessary, because the calculation of the volume of CO_2 from weight of CO_2, as based upon the analysis or titration of the lime- or baryta-water, is expressed in these terms, and the conditions in both cases must be alike in order to compare them. Besides these necessary corrections for temperature and pressure, the volume of the 60 c.c. of lime- or baryta-water put in the jar must be deducted before the net volume of air in the vessel can be accurately stated.

The milligrammes of lime or baryta, calculated from the difference of the causticities, are next converted into terms of CO_2 by calculation of the ratio between their molecular weights, and then the CO_2 converted from milligrammes or measures of weight into cubic centimetres or measures of volume, in the ratio of as 1·9707 is to 1; because carbon dioxide being 22 times heavier then hydrogen, and 1 litre of hydrogen at 0° C. and 760 mm. weighing 0·08958 gramme, therefore 1 litre of CO_2 at 0° C. and 760 mm. weighs $22 \times 0{\cdot}08958 = 1{\cdot}9707$ gramme, and 1·9707 milligramme of CO_2 under standard conditions of temperature and pressure measures 1 c.c. Having determined the exact volume of CO_2 present in the known volume of air, the proportion present is readily expressed as either a percentage or as so many parts in a thousand. The precise working of this determination will be more readily apparent after the consideration of an example.

Example.—Say, in a room with the temperature at 20° C. and barometric pressure at 720 mm., a sample of air is collected in a jar, having a capacity of 4·460 litres, and that 60 c.c. of lime-water are placed in the vessel for estimation of the contained CO_2. Whilst the jar is set aside, 30 c.c. of the lime-water are titrated with the oxalic acid solution, neutrality being obtained with 40 c.c. of this acid solution, indicating 40 mgms. of lime as being present in the lime-water. The gross capacity of the jar is recorded to be 4460 c.c., but, deducting 60 c.c. for the space occupied by the added lime-water, this gives 4400 c.c. nett as the space available for the air sample at the recorded current temperature and pressure of 20° C. and 720 mm. This, reduced to the standards of 0° C. and 760 mm., gives 3885 c.c. as the corrected volume of air operated upon, or really present, in the jar under standard conditions of temperature and pressure: thus—

$$V = \frac{4400 \times 720}{760(1 + (0{\cdot}00366 \times 20))} = 3885 \text{ c.c.}$$

Presume, after being exposed to the action of the air in the jar, 30 c.c. of the lime-water removed from the vessel, show a causticity equal to 34 c.c. of the oxalic acid solution, indicating the presence in that lime-water of 34 mgms. of lime. The difference between the amount of lime and that shown to be present in 30 c.c. of lime-water before exposure to the air gives 40 – 34 or 6 mgms. of lime as having combined with the CO_2 of the air sample from 30 c.c.; but as 60 c.c. of lime-water were put in, this means 12 mgms. of lime as the total loss due to the CO_2. Since lime, CaO, is to carbon dioxide, CO_2, as 56 is to 44, therefore 12 mgms. of lime equal 9·4 mgms. of CO_2. But milligrammes of CO_2 are to cubic centimetres of CO_2 as 1·9707 is to 1, therefore 9·4 mgms. CO_2 equal 4·76 c.c. of CO_2. Now the true capacity of the jar, under standard conditions, we have found to be 3885 c.c., and in this we have found 4·76 c.c. of CO_2, which is, in amount, equal to 1·22 c.c. or volumes of CO_2 in 1000 c.c. or volumes of air.

The foregoing method has the disadvantage that the determinations

necessitate the carrying to and fro of large bottles, and take a considerable time. To overcome these drawbacks several methods capable of being applied conveniently on the spot have been devised; probably the most accurate is one suggested by Haldane,* but even this requires a certain adeptness and some practice to yield good results. Once this facility of manipulation has been acquired, however, its advantages are great, as an accurate result can be obtained within ten minutes and no calculations are required. To make an estimation of carbon dioxide by this method, a special apparatus (Fig. 7) needs to be used. It consists virtually of a gas analysis instrument, consisting of a burette with a wide ungraduated portion and a narrow portion graduated in divisions of $\frac{1}{10000}$th part of the capacity of the burette. This is enclosed in a water-jacket, and a control-tube is used to correct for variations of temperature. The pressures under which the readings are made are found to be the same, before and after absorption, by measuring the level of the potash solution in the narrow tube. The graduated burette allows of 25 c.c. of air to be admitted for examination. Having collected the amount of air the carbon dioxide is absorbed in the caustic potash solution. After complete abstraction of carbon dioxide the volume of the air is again read off at the same temperature and pressure. The difference between the two readings gives the result in volumes of carbon dioxide per 10,000 of air.

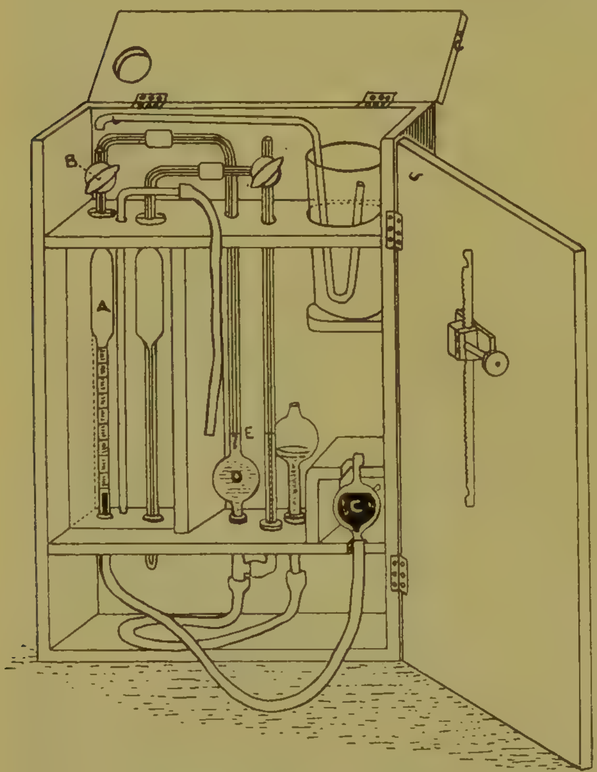


Fig. 7.—Haldane's Apparatus for estimating Carbon Dioxide in Air.

In using the apparatus the air is first expelled from the gas burette A by opening the three-way tap B to the outside and raising the mercury-bulb C. The tap is then closed, and the mercury-bulb replaced in its stand. On opening the three-way tap again a sample of the air is drawn in, and the level of the mercury falls to near the zero mark. The tap is now opened towards the absorption pipette D, which is filled up to a mark at E with potash solution, and the sample measured with certain precautions fully detailed on the instructions which accompany the instrument. The air sample is then passed over into the absorption pipette, driven backwards and forwards for a few seconds, and then again measured after the absorption of the carbon dioxide. The difference between the two readings gives directly the number of volumes of carbonic acid per 10,000 in the sample of air.

It must be understood that none of the methods hitherto used for the determination of carbon dioxide in the air give quite accurate results, but

* Haldane: "A Rapid Method of determining Carbonic Acid in Air," *Journal of Hygiene*, vol. i. p. 109.

Pettenkofer's is the most convenient for ordinary use, and is sufficiently accurate for practical purposes.

Determination of the Organic and Oxidisable Matter.—The nitrogenous matter existing in the air may be in the form of dead or living matter of very various kinds. Its chemical determination practically resolves itself into washing the air, by agitation in distilled water, and then estimating the nitrogen, the free and albuminoid ammonia, as well as the nitrous and nitric acid as described in methods of water analysis. The mere presence of free ammonia may be determined by exposing strips of filtering paper, dipped in Nessler's solution or in ethereal solution of the alcoholic extract of logwood; the former becomes yellow, the latter purple.

Estimation of Carbon Monoxide.—The examination of the blood for carbon monoxide is not a difficult matter. The easiest and most delicate method is to compare the tint of a greatly diluted solution of the suspected sample with that of normal blood similarly diluted. The latter is yellow, while blood containing even very small traces of carbon monoxide is pink.

When the proportion of carbon monoxide in the blood is more than 40 per cent. of saturation (and usually death does not result in man until the proportion reaches 60 to 80 per cent.), spectroscopic examination of the blood affords a confirmatory test. To the sample of air collected in a jar pure water is added, and into this a drop or two of blood from a pricked finger is made to fall, so as to make a dilution of about 1 in 300. This diluted blood is next well shaken up with the air in the jar, and then a small quantity is placed in a spectroscope, for an examination of its absorption bands. As so examined, the appearance in the spectrum will closely approximate to that of oxy-hæmoglobin. Oxidised hæmoglobin shows two well-marked bands in the yellow and in the green parts of the spectrum, both lying between D and E; a little ammonium sulphide is now added and the bottle well shaken; if carbon monoxide is present the spectrum will undergo no change, but if absent, the ammonium sulphide will reduce the hæmoglobin as indicated by a single absorption band in the spectrum occupying an intermediate position with regard to the two original bands.

An alternative method is the following. Fit up a U-tube with glass-stoppered connections containing iodic anhydride maintained at a temperature of 68° C. At this temperature, iodic anhydride is decomposed by even small traces of carbon monoxide, giving iodine. If the U-tube be suitably connected with a bulb containing dilute soda solution, any iodine liberated from the iodic anhydride as air is aspirated through it, passes over into the bulb and is absorbed by the contained soda solution. The amount is estimated at the end of the aspiration of the air through the tube and bulb by acidifying, adding a little dilute sodium nitrate solution, and shaking out the liberated iodine by means of chloroform. The pink-violet tint of the chloroform can be compared, in a series of comparison colour-glasses, with that given by a standard solution of potassium iodide, and the corresponding quantity of carbon monoxide calculated.

Haldane has devised the following method of determining the extent to which blood is saturated with carbon monoxide. A solution of about 1 of normal blood to 100 of water is made; also a solution of carmine dissolved with the help of a little ammonia and diluted till its depth of tint is about the same as that of the blood solution. Two test-tubes of equal diameter (about half an inch) are selected. Five c.c. of the solution of normal blood are measured into one of the test-tubes and a drop of the suspected blood placed in the other test-tube and cautiously diluted with water till the depth of tint is about equal to that of the normal solution. If carbon monoxide be

present in the hæmoglobin, a difference of quality in the tints of the solutions will now be clearly perceptible. Carmine solution is then added from a burette to the normal blood and water, if necessary, to the abnormal blood, till the tints are equal in both quality and depth. The solution of abnormal blood is then saturated with coal gas, and the addition of carmine to the other test-tube continued until equality is again established and the amount of carmine noted. Example:—To 5 c.c. of normal blood solution 2·2 c.c. of carmine is required to be added to produce the tint of the blood under examination, and 6·2 c.c. to produce the tint of the same blood fully saturated. In the former case the carmine was in the proportion of 2·2 in 7·2 and in the latter of 6·2 in 11·2. The percentage saturation (x) of the hæmoglobin with carbon monoxide is $\frac{6·2}{11·2} : \frac{2·2}{7·2} :: 100 : x$; x is therefore 55·2. As the compound of carbon monoxide and hæmoglobin is to a slight extent dissociated when the blood is diluted with water, the value found is a little too low. The corrections needed are as follows: add 0·5 if 30 per cent. saturation be found, 1·1 if 50 per cent., 1·6 if 60 per cent., 2·6 if 70 per cent., 4·4 if 80 per cent., 10 if 90 per cent.

The above method can be utilised for the determination of small quantities of CO in air. The sample of air is collected in a clean and dry bottle of about 4 ounces capacity. The cork is removed under a 0·5 per cent. solution of blood, and about 5 c.c. of the air allowed to bubble out, a corresponding volume of blood solution entering. The cork is then replaced, and the bottle, covered with a cloth, is shaken for ten minutes. The solution is then passed into a test-tube and its saturation with CO determined as above. To calculate the percentage of CO (p.) the following formula is used, viz., $p. = \frac{3 \times 0·07}{100 - S}$. Thus if S, the percentage saturation, be 60, p. is 0·105.

When carbon monoxide is suspected of existing in the air in large quantities, an estimation of this gas can be made by noting the volume of air absorbed by a solution of subchloride of copper in a Hempel apparatus. The subchloride of copper is prepared by digesting oxide of copper and copper turnings in strong hydrochloric acid. Since the presence of oxygen in the air somewhat impairs the powers of the copper solution, it is necessary, in order to carry out successfully this estimation, to first remove the oxygen, as already described, and then pour 50 c.c. of acid subchloride of copper solution into an absorption pipette, into which the air sample (now deprived of oxygen) must be repeatedly passed until a constant reading is obtained. The loss, in volume, is due to carbon monoxide.

Determination of Ozone and Watery Vapour.—The most common test for ozone is that of exposing to the atmosphere faintly reddened litmus paper, which has been moistened with potassium iodide and then dried. If ozone be present, this becomes blue, owing to the breaking up of the potash salt and liberation of alkali.

The hygrometric condition of the air is ascertained in various ways, especially by the use of the dry and wet bulb thermometer and different kinds of hygrometer. The special facts relating to their construction and methods of use are given in the chapter upon meteorology.

Determination of Sulphurous Acid.—For this estimation are required (1) a deci-normal solution of sodium thiosulphate, made by dissolving 24·8 grammes of $Na_2S_2O_3 5H_2O$ in a litre of distilled water. One c.c. of this solution will exactly decolourise 12·65 milligrammes of iodine, forming colourless sodium tetrathionate and sodium iodide; (2) a deci-normal solution of iodine made by dissolving 12·65 grammes of iodine in a

litre of water. As iodine is rarely very pure and somewhat volatile on weighing, it is usually better to prepare the solution by dissolving 13 grammes of iodine, rubbing it up in a little water with 20 to 25 grammes of potassium iodide, diluting to 1 litre, and diluting still further until 10 c.c. of the preceding deci-normal sodium thiosulphate solution exactly suffice to decolourise 10 c.c. of the iodine solution, which has been coloured blue by the addition of a few drops of starch solution.

The experiment is carried on by exposing a given volume of air to, say, 20 c.c. of the iodine solution in an absorption pipette, when the following reaction ensues if sulphurous acid be present: $SO_2 + I_2 + 2H_2O = SO_4H_2 + 2HI$. In other words, 64 milligrammes of sulphurous acid exactly convert 253 milligrammes of iodine into hydrogen iodide, or 3·2 milligrammes exactly decolourise 1 c.c. of a deci-normal solution of iodine.

If, after exposure to a given volume of air for ten minutes in an absorption pipette, as already described under the head of oxygen determination, the iodine solution be titrated with the deci-normal solution of sodium thiosulphate, each decrease of a c.c. of the thiosulphate solution required indicates 3·2 milligrammes of sulphurous acid as present in the given volume of air.

Determination of Hydrogen Sulphide.—The quantitative estimation of this gas can be made in air in a similar manner. One c.c. of deci-normal iodine solution decomposes 1·7 milligramme of sulphuretted hydrogen; therefore each c.c. of the sodium thiosulphate solution *less* used after absorption than for the titration of the same volume of the original solution of iodine, indicates the equivalent absorption of 1·7 milligramme hydrogen sulphide. The amount present, then, in 1000 volumes of the air is readily calculated.

Examination of Suspended Matter and Micro-organisms.—From time to time various methods have been suggested for the examination of the suspended matters in air. One of the earliest methods was to aspirate large volumes of air slowly through distilled water, placed in a series of small wash-bottles, each holding about 100 c.c. The suspended or solid matter was allowed to settle, the supernatant fluid siphoned off and the specimens from the residue examined microscopically.

The simplest methods for examining the micro-organisms in air consist in exposing plates of glass or microscopic slides coated with glycerin, or a mixture of glycerin and glucose, or even coated with nutrient gelatin. Sterilised potatoes have been similarly exposed. Upon these various micro-organisms settle and subsequently develop; all these procedures are, however, crude and open to many sources of error. When specimens are only desired, and not an idea of the number for a given volume of air, Koch's method is useful. He employs a glass jar about 6 inches high, the neck of which is plugged with cotton-wool. In the interior is a shallow glass capsule, which can be removed by means of a brass lifter. The whole is sterilised by exposure to 150° C. for an hour. The nutrient gelatin of an ordinary stock tube is liquefied by heat and the contents emptied into the glass capsule. The jar is now exposed to the air to be examined, for a definite time, the cotton-wool plug replaced, and the whole jar set aside for the colonies to develop.

For more accurate results Hesse's apparatus may be employed (Fig. 8). This consists of a glass cylinder about 18 inches long and 2 inches in diameter. At one end a piece of india-rubber sheeting is stretched and firmly bound round the end of the glass cylinder to prevent air being sucked past it. The other end of the cylinder is closed with a tight-fitting plug of india-

rubber, through which a glass tube passes. From this tube passes a piece of india-rubber tubing to a litre bottle filled with water, and from this bottle to a second litre bottle another tube passes; when not in action, this tube is shut off. Along the bottom of the glass cylinder are placed 50 c.c. of nutrient jelly, solid when cooled. The cylinder rests on a tripod stand similar to those used by photographers. The nutrient jelly, india-rubber caps, tubing, cylinder, &c., are sterilised in the usual manner by steaming in a steriliser repeatedly, and the tubes with their layers of jelly are kept sufficiently long, before using, to see that there is nothing growing upon them. When it is wished to examine an air sample, the india-rubber sheeting is perforated by a heated needle or pin, making a very small hole, and the pinch-cock opened; water passes slowly from the upper to the lower bottle, and when it is empty a litre of air has been supposed to pass into the cylinder, and to deposit its contained microbes. As many litres of water as desired can be run out simply by reversing the position of the bottles. When the air is very foul, one litre will be sufficient, as the colonies otherwise would be too close and run into each other. When the operation is over, sterilised indiarubber caps or pieces of cotton-wool, also sterilised, are bound over the ends of the Hesse tube, and it is then placed in either an incubation chamber or other suitable place. After twenty-four hours or longer, the colonies may be counted. At one time the glass cylinders were used with a coating of gelatin all round the interior, but this is difficult to obtain, and in practice it is found that the microbes gravitate and settle on to the layer at the bottom of the tubes. The method of Hesse is very elegant, and has many advantages; from the length of the surface of the jelly exposed, separate colonies form, often giving pure cultivations, and their growth can be studied as on a glass plate, and inoculations can be readily made in the usual manner.

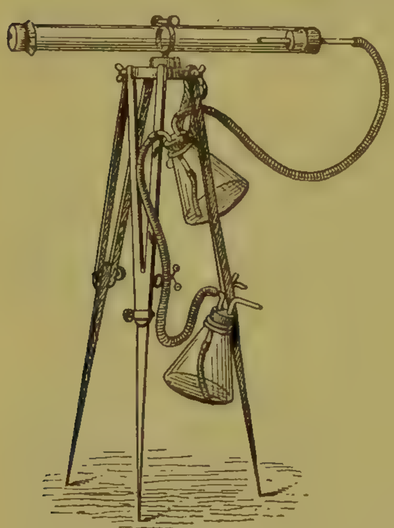


Fig. 8.—Apparatus for the Bacteriological Examination of Air.

There are undoubtedly objections, some of which apply to all bacterial methods, and others which apply specially to this one in particular. The chief objection appears to be that, although a litre of water is run off, and although the capacity of the glass cylinder is also about a litre, it does not follow that a litre of air has been drawn from the outside. The first half of the air contained in the glass cylinder may be removed, but after that, or even before, the air from the outside and the air inside diffuse and commingle, so that a mixture of these will be aspirated out, and in consequence a litre of air will not have been examined. This defect makes the method doubtful as a quantitative test. Another objection is, that one cannot be sure that all microbes are deposited; true, we find in practice that the colonies are found in greatest abundance at the end furthest from the aspirator and gradually diminish inwards, but still one cannot be certain that some micro-organisms have not escaped. Notwithstanding these objections, the method is one of considerable practical value.

In order to obviate some of the difficulties and objections experienced with Hesse's apparatus, Percy Frankland aspirates the air through small glass tubes, 5 inches long and $\frac{1}{4}$ inch internal diameter, in which are placed

two plugs of sterilised glass-wool; these plugs retain the germs, and are then introduced into flasks containing nutrient gelatin, and well shaken up. The gelatin solidifies on the sides of the flask, and the colonies can be examined readily through the glass. The glass-wool mixes so intimately with the gelatin that it does not interfere with the easy perception of colonies when they develop.

Sedgwick and Tucker suggested one of the best methods for the bacteriological examination of air. A glass tube of special form is employed; this consists of an expanded portion about 15 cm. long and 4·5 cm. in diameter, which at one end terminates in a contracted neck about 2·5 cm. in diameter; to the other end is fused a narrow tube 15 cm. long and 0·5 cm. wide. The neck of the tube is plugged with cotton-wool and two plugs are inserted in the narrow part of the tube, one at the end and one about 6 cm. from the expanded portion. The whole is sterilised, and when cool the narrow part of the tube from its insertion to the first plug is filled with cane-sugar, which has been carefully dried and sterilised at 120° C. The tube is again sterilised at 120° C. for three hours, taking care not to melt the sugar. When in use the narrow part of the tube is attached to an aspirator, and the cotton-wool plug having been removed from the neck, a known volume of air is drawn through the sugar. The cotton-wool is then replaced and the sugar shaken down into the wide part of the tube; 15 c.c. of melted gelatin are then poured into the expanded portion of the tube, the sugar readily dissolves, and a roll-culture is then made in the tube. When the gelatin is firm, the tube is incubated at 22° C., and the colonies allowed to develop for as long a time as possible; a count should be made daily in the event of the gelatin becoming liquefied.

A very similar plan is that of Petri, who employs calcined sand as a filter, in grains of 0·25 to 0·5 mm. in size. Two such sand filters, each 3 centimetres in length, are kept in position within small glass tubes by means of small wire caps. The whole, after sterilisation, is connected with an aspirator and air drawn through, the sand being subsequently transferred to liquefied gelatin as in Frankland's method.

It is impossible to say definitely, at present, which of these methods is the best; but a large number of observations indicate that the use of glass-wool or of sand filters, with a subsequent preparation of plate cultures from them, is preferable to the growth of colonies in a long tube, such as Hesse's. We, ourselves, are disposed to think that probably the simplest and most effective way of gaining a knowledge of the nature of exhaled organic matter as present in the air of inhabited rooms is to expose Petri-dishes containing either gelatin or agar for definite periods of time and then to examine the colonies which result or grow from the suspended matter which settles on them from the air.

The actual varieties of micro-organisms which have been found, by one or other of these methods, in air, are considerable, and in the majority of cases moulds are much less frequently found than bacteria. The purer air is, the more generally do the numbers of bacteria and moulds approximate. In inhabited rooms, when the air becomes vitiated, the bacteria increase, while the moulds are affected hardly at all. Gordon's work in connection with the ventilation of the Houses of Parliament indicates that, as a bacterial measure of human pollution, certainly by droplets of saliva, of the air the *streptococcus brevis* is most reliable and delicate. This test is so delicate that even a particle of saliva so minute as one ten-millionth of a c.c. can be detected. Apart from the human mouth and air passages as a source of bacterial vitiation of the air of inhabited rooms, it is probable that ordinary

horse-dung and road litter is the chief agency at work in polluting the air in and around our dwellings. From this material, many *B. coli*, *B. mycoides*, *B. enteritidis sporogenes* and other micro-organisms common in the air are undoubtedly derived, being either blown in through doors and windows or brought into rooms on boots and clothes.

The effect of stirring up dust is to increase the ratio of bacteria to moulds. On the other hand, if the air be allowed to remain quiet for any length of time, the bacteria, or rather the particles to which they are attached, settle down much more rapidly than moulds.

CHAPTER IV

VENTILATION AND HEATING

In the last chapter sufficient evidence was given to indicate the intimate connection between impaired health, whether in man or animals, and defective air-supplies, as to render any repetition of either facts or figures unnecessary here. The theory and practice of ventilation aims essentially at correcting any evils arising from faulty conditions of the air in houses, factories, or other enclosed spaces. The term "ventilation," however, is not always used in the same sense, being frequently confused with aeration. In simple aeration of a room the air is changed but once or at intervals, whereas in true ventilation the air is constantly changed by the passing out of a portion of the enclosed air, and the entrance of other air to take its place. Regarded, therefore, as the continuous, and more or less systematic, renewal of air in a room or other closed space, the term "ventilation" may be strictly defined as the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men or animals, and of the products of combustion from lights in ordinary dwelling-houses, to which must be added, in factories, dust from industrial processes, and in hospitals the effluvia which proceed from the persons and discharges of the sick.

Involving, as it does, the introduction of pure external air in continuous currents, its diffusion, and the constant removal of a corresponding volume of air more or less fouled by gases, vapours, moisture, and particulate matter, or heated above the degree which is consistent with comfort and health, the subject of ventilation is one of some complexity, and is closely connected with the facts which concern the production and distribution of heat. In studying, therefore, the allied subjects of ventilation and heating, we have to remember the chemical and physical properties of air, to bear in mind the various sources of its contamination, as well as the forces which are available for moving it in the direction best suited for our purpose, coupled with a consideration of the arrangements of flues, shafts, &c., best adapted to secure the entrance, diffusion, and exit of the amount of air required.

Notwithstanding the existence of a vast amount of literature upon these subjects, both from the purely hygienic and the purely engineering or architectural points of view, still the conditions of ventilation and heating in the greater number of dwellings and public buildings must be said to be unsatisfactory. In this country the great majority of habitations have no systematic scheme of, or special provisions for, ventilation, and even in the greater number of churches, schools, theatres, courts of justice, and public assembly-rooms, in which some openings do exist for the entrance and exit of air, it is rare to find satisfactory ventilation. The causes of this appear to be partly apathy and ignorance on the part of the people, partly an inability on the part of architects and engineers to accept a definite standard as to quantity of air required, and partly the question of cost. In respect of this last factor, it is important to remember that in most cold climates it is difficult to combine good ventilation and sufficient heating with cheapness

of construction in building; possibly the question of expense might be considerably modified, were the matter of ventilation and heating duly considered in the beginning, and not taken up as an after-thought when every detail as to construction has been decided upon. When this fact is more fully appreciated by architects and builders, doubtless considerable improvements, as to both ventilation and heating, will soon be apparent.

QUANTITY OF AIR REQUIRED FOR VENTILATION.

The quantity of air required for ventilation will naturally depend upon the nature and amount of the air impurities requiring dilution and removal. These have been already considered in the preceding chapter, and, disregarding details, practically consist of impurities from respiration and from artificial lights. Of these various impurities, no matter whether from respiration or illumination, the carbon dioxide is accepted as the chief measure of air vitiation. This is so, not because the carbon dioxide exists in such amount as to influence health, but because it appears to exist in a constant ratio with the other offensive and possibly more dangerous impurities. And as it is very readily determined with sufficient accuracy for practical purposes, it is taken as a convenient index to the amount of the other impurities in general.

Fresh Air Requirements of the Healthy.—Taking the carbon dioxide as the measure of the impurity of the air vitiated by respiration and transpiration, in short, from the person in any way, we have to ask, What is to be considered the standard of purity of air in dwelling-rooms? We cannot demand that the air of an inhabited room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can ensure perfect purity at every respiration. In every dwelling-room there will be some impurity of air.

The practical limit of purity will depend on the cost which men are willing to pay for it. If cost is disregarded, an immense volume of air can be supplied by mechanical contrivances, but there are comparatively few cases in which this could be allowed.

Without, however, attempting too much, it may be fairly assumed that the quantity of air supplied to every inhabited room should be sufficient to remove all sensible impurity, so that a person coming directly from the external air should perceive no trace of odour, or difference between the room and the outside air in point of freshness. This is now generally admitted as the most convenient practical standard, precautions being taken that the air space be entered directly from the external air, or as nearly so as possible, for the sense of smell is rapidly dulled.

In 1875, de Chaumont showed from a large number of observations that the sense of smell, carefully employed, gives a very fair idea of the amount of impurity in an air space. In these experiments, the amount of carbon dioxide in the external air was determined at the same time, so that the respiratory impurity was accurately known. The general inference to be drawn from de Chaumont's work was that the smell of organic matter is, on an average, imperceptible to the sense of smell when the coincident CO_2, due to respiratory (or personal) impurity, does not exceed 0·1943 per 1000; and that when it reaches 0·9054, smell is no longer able to detect shades of difference. We may therefore take 0·2 per 1000 in round numbers as the maximum amount of respiratory impurity admissible in a properly ventilated air-space.

The relation between the smell and air vitiation of an inhabited room varies greatly under certain circumstances. Thus the smell of organic contamination from respiration may not be perceptible when the CO_2 is as high as 0·5 per 1000, and yet be very decided when the CO_2 does not exceed 0·3 per 1000. These differences depend largely upon the amount of moisture present and the temperature.

In adopting any standard of air purity, as expressed by the proportion of carbon dioxide present, we must not forget that, although hitherto it has been assumed that the carbon dioxide found, in excess of that which exists in the outer air, is all due to respiration, such is not always the case. Some may be due to gas or candles. Similarly, in instances where some of the air impurity may not be readily appreciable by a chemical test, the vitiation as indicated by a greater or less amount of carbon dioxide may be wide of the mark. Subject to these considerations, we may practically accept the carbon dioxide present in any given air sample as the best and most reliable index of air pollution.

Having fixed upon a standard of respiratory impurity permissible in a properly ventilated air-space, it is easy to calculate the amount of air needed to dilute the air expired by a person for a given time, so that the carbon dioxide contained in the resulting mixture shall not exceed this standard. The amount of carbon dioxide, over and above that in the inspired air, which is expired by an individual during an hour, varies with his weight and body activity.

For a mixed community a general average of 0·6 of a cubic foot per hour may be adopted ; but for adult males, such as soldiers, it is advisable to adopt 0·7 to 0·72.

By dividing the amount of carbon dioxide exhaled in an hour by the permissible limit of respiratory impurity, de Chaumont suggested the number of cubic feet of air per hour required per person ; this is now the standard most generally accepted by all sanitarians. It is conveniently expressed by the following formula :—

$$\frac{e}{\rho}=d,$$

where e = the amount of CO_2 exhaled by one individual in an hour, ρ = the limit of admissible impurity (stated per cubic foot), and d = the required delivery of fresh air in cubic feet per hour. If we take e at the general average of 0·6 of a cubic foot, then $\frac{0·6}{0·0002}=3000$; or, putting e at a higher figure, say 0·7, then $\frac{0·7}{0·0002}=3500$; or, putting e still higher, say 0·92, then $\frac{0·92}{0·0002}=4600$.

For mixed communities, under ordinary conditions, 3000 cubic feet per hour is the accepted standard allowance per person.

This formula may also be used conversely, in order to find from the condition of the air the average amount of fresh air which has been hitherto supplied and utilised. For this purpose we simply substitute for ρ (the admissible limit) ρ_1, the observed ratio: thus, $\frac{e}{\rho_1}=d$.

Example.—Let us suppose that the total CO_2 in a room, after occupation, is found to be 1·1 per 1000, or 0·0011 per cubic foot, that in the outer air being 0·0004 : therefore ρ_1, or the observed ratio of respiratory impurity, is 0·0011 – 0·0004 or 0·0007 ; then $\frac{e}{\rho_1}=d$, or $\frac{0·6}{0·0007}=857$ cubic feet of air, have been supplied during the period of occupation.

By a transposition of the last formula, we can calculate the probable condition of the atmosphere in a room into which a given quantity of air has been or is being delivered; thus, $\frac{e}{d}=\rho_1$.

Example.—If five persons occupy a room of 6000 cubic feet space for six hours, what percentage of CO_2 would be present at the end of the time, supposing 8000 cubic feet of fresh air have been supplied per hour?

Presuming that each person gives off 0·6 cubic foot of CO_2 per hour, therefore five persons in six hours exhale $0·6 \times 5 \times 6 = 18$ cubic feet of CO_2, and this will represent e or the observed ratio of respiratory impurity: d, or total amount of fresh air available, will be 54,000 cubic feet, because 6000 were originally present in the room and 48,000 are added during the six hours; then,

$$\frac{e}{d}=\rho_1 \text{ becomes } \frac{18}{54000}=\rho_1, \text{ or } 0·00033 \text{ per cubic foot or } 0·033 \text{ per cent.}$$

That is, the added respiratory impurity is 0·033 per cent.; but the air of the room originally may be presumed to have contained 0·04 per cent. of CO_2, therefore the total percentage of CO_2 in the air asked for $=0·033+0·04$ or 0·073 per cent.

It must be observed that in applying these formulæ, the primary value of e must be changed with different conditions. For children, it averages 0·4; for adults under ordinary circumstances, 0·6; for adult males, such as soldiers, 0·72 has been suggested; while for adults employed in arduous work, possibly as much as 2 cubic feet may be taken as the average hourly exhalation of carbon dioxide.

It is highly desirable that some general agreement should be come to as to the amount of air necessary, even if it be admitted that the desired amount cannot always be obtained. If we adopt the following amounts of CO_2 as being evolved during repose, we shall not be far from the probable truth:—

Adult males (say 160 lb. weight)	0·72 of a cubic foot.
„ females („ 120 lb. „)	0·6 „
Children („ 80 lb. „)	0·4 „
Average of a mixed community . . .	0·6 „

Under those conditions the amount of fresh air to be supplied in health during repose ought to be:—

For adult males . .	3600 cubic feet per head per hour	=102 c.m.
„ „ females . .	3000 „ „ „	= 85 „
„ children . . .	2000 „ „ „	= 57 „
„ a mixed community .	3000 „ „ „	= 85 „

The amount for adult males as above given is just over 100 cubic metres, or, if we state it at 3600 cubic feet, it is just 1 cubic foot per second. These numbers are easy to remember.

When we have to deal with places, the inmates of which are actively employed, such as workshops and the like, the amount of air supplied must be proportionately increased. We have seen that in light work the carbon dioxide evolved per hour is nearly 0·006 of a cubic foot per lb. of body-weight, and in hard work more than double that amount—so that for a man of 160 lb. weight we should have—

In light work . .	0·95 of a cubic foot of CO_2 evolved per hour.
In hard work . .	1·84 „ „ „

This would argue a delivery of fresh air as follows:—

In light work	4750 cubic feet.
In hard work	9216 „

Carnelley, Haldane, and Anderson,* basing their opinion not only upon the average presence of carbon dioxide in the air, but also upon the organic

* Report on the Ventilation and Heating of Schools to the School Board of Dundee, 1889; also *Proc. Roy. Soc. Lond.*, 1887.

matter and number of micro-organisms, proposed that instead of taking 0·6 cubic foot of CO_2 per 1000 as the limit, that the standard should be 1·0 for dwellings and 1·3 for schools. In the case of organic matter, that not more than two volumes of oxygen should be required for oxidation per million volumes of air, and that the micro-organisms should not exceed 560 per cubic foot of air. The above figures for carbon dioxide are inclusive of that ordinarily present in the air, and certainly give a very liberal margin, which ought not to be transgressed. If accepted, the respiratory impurity permissible in dwellings would be as high as 0·6 for dwellings and 0·9 for schools, in place of de Chaumont's general permissible respiratory impurity of 0·2. On this basis, the hourly need of fresh air in dwellings would not exceed 1000 cubic feet per head, and in schools be but 550 cubic feet. Experience, so far, has not justified the general acceptance of those low standard allowances of fresh air per hour.

In mines, experiments show that, if it is wished to keep up the greatest energies of the men, no less than 6000 cubic feet per hour must be given ; if the quantity be reduced to a third or half, there is at once a serious diminution in the amount of work done by the men. This amount of fresh air includes, of course, all that wanted in the mine for horses, lights, &c.

Fresh Air Requirements of the Sick.—In making differential experiments among the healthy and the sick, it was found that among the former the smell of organic matter was still imperceptible when the air contained 0·208 per 1000 of respiratory impurity as carbon dioxide ; but in hospitals containing ordinary cases it was quite distinct when the CO_2 reached 0·166. From this we may conclude that the minimum amount of fresh air for hospitals ought to exceed that required in health by at least *one-fourth*. If 3000 cubic feet per hour be admitted as a general average in health, we may demand in round numbers 4000 in sickness ; and if we have to deal with adult males only, such as soldiers, 4500 per head per hour. When we have to deal with serious cases, a still greater amount must be given, reaching 5000, 6000, or even more if possible—in fact, the supply should be unlimited. These views are in accordance with the results of experimental inquiry.

Fresh Air required for Artificial Lights.—The same principles which govern the calculation of fresh air, needed to dilute and remove respiratory impurities, apply equally to the case of air vitiation from gas lights, lamps, and candles. If the products of their combustion are allowed to pass into rooms, fresh air must be supplied to dilute and remove them. Although the contaminations, especially in the case of gas, are very great, it is estimated that for their proper dilution the amount of fresh air-supply, in relation to the carbon dioxide evolved, need not be so great in their case as for breath impurities. It has been calculated that for every cubic foot of coal gas burnt, 500 cubic feet of fresh air must be introduced hourly to properly dilute the products of combustion ; and this is not too much if we remember that a cubic foot of good coal gas produces 0·5 cubic foot of carbon dioxide, and that sulphur dioxide and other substances may be also formed. An ordinary flat-flame burner will burn at least 5 cubic feet of gas per hour, and in the course of an evening of four hours will generate at least 10 cubic feet of carbon dioxide, and, assuming that a supply of 1000 cubic feet of fresh air are needed for every cubic foot of carbon dioxide produced per hour, we shall require for this gas-burner alone some 10,000 cubic feet of air to be supplied during the evening, or about 2250 cubic feet per hour ; unless, of course, the products of combustion are removed by a special channel. We have already seen that, the power of

illumination being equal, gas produces less carbon dioxide than candles; but usually so much more gas is burnt that the air is much more contaminated; there is also greater heat and more watery vapour. The carbon dioxide and aqueous vapour should never be allowed to escape into the air of a room, for the bad effects of breathing the products of gas combustion are only too well known.

One lb. of paraffin oil demands for complete combustion 138 cubic feet of air; and to keep the air perfectly pure, nearly as much air must be introduced for 1 lb. of oil as for 15 cubic feet of gas. In mines, 60 cubic feet of air per hour are allowed for each light; the lights, however, are usually dim and the combustion imperfect, facts which indicate the fresh air allowance to be inadequate. Speaking generally, and under equal conditions of illuminating power, an ordinary 5-foot, flat-flame gas-burner needs two-thirds the supply of fresh air per hour as required by an adult: the incandescent gas-lights on Auer's principle appear to need slightly less or about half the amount proposed for grown-up individuals, while ordinary paraffin lamps need quite as much fresh air as do adults. If gas is burnt in a room only in small quantities, or if only a few candles or a small oil lamp are used, it is seldom necessary to take them into account in estimating the amount of fresh air required; but where many gas-burners are used, or many candles and lamps are alight, the degree of air vitiation resulting from them needs to be considered in estimating the amount of fresh air to be supplied to inhabited rooms, in order to keep the contained atmosphere in a sufficient state of purity consistent with comfort and health. Hitherto this point has been much neglected. The general use of incandescent electric lamps entails no extra provision of fresh air, as they do not contribute any impurity to the atmosphere.

Fresh Air required for Animals.—This is a matter which has not received much attention, though very important. Märcker gives the following:—

For *large* cattle (viz., oxen, &c.) 30 to 40 cubic metres per hour for every 1000 lb. weight, or 1 to $1\frac{1}{2}$ cubic foot for every pound of weight.

For *small* cattle (viz., sheep, &c.) 40 to 50 cubic metres per hour for every 1000 lb. weight, or $1\frac{1}{2}$ to $1\frac{3}{4}$ cubic foot for every pound of weight; the higher quantity being given on account of the more rapid tissue change in the smaller animals. These quantities seem absurdly small, and the chief reason for so limiting them seems to have been the fear of lowering the temperature too far. This is an erroneous view; animals properly fed will thrive better in a well-ventilated place at a low temperature than in a warmer place ill-ventilated. There seems no reason why the same rule should not apply to animals as to man, in which case something like 20 to 25 cubic feet per hour per pound of body-weight ought to be supplied. A horse or a cow ought, therefore, to have from 10,000 to 20,000 cubic feet per hour—in short, it ought to be practically in the open air.

From F. Smith's experiments, and using de Chaumont's formula, $\frac{e}{\rho}=d$, where e (in a horse) equals 1·13, it is shown that the amount supplied ought to be 5650 cubic feet per hour, if the limit of respiratory impurity be assumed at 0·2 per 1000. From the experiments given in Smith's work the amount of air supplied ranged from 38,000 cubic feet per hour to 2900; in the latter case the smell is described as abominable. It is clear, therefore, that the amount of air ought to be as large as possible, and fortunately in the case of animals this can be accomplished without any great difficulty; as F. Smith considers that with proper feeding and attention the air about a

horse may be changed every three minutes, or twenty times an hour, without danger, although the coat may not turn out so glossy as in a warmer stable.*

Carl Dammann † estimates that a horse or a cow weighing 1000 lb. should have 50 cubic metres of air or about 1800 cubic feet per hour for ventilation. For small animals he estimates that the supply should be 60 cubic metres or 2100 cubic feet of air per hour for each 1000 lb. of animal weight. The smaller animals appear to require more air in proportion to their weight than do the larger ones, while the so-called wild animals need more than the domesticated. Monkeys, in particular, require a comparatively liberal allowance of fresh air to keep them in good health.

Fresh Air required for Removal of Moisture.—In all the foregoing considerations the chief need of fresh air has been emphasised in special reference to the removal or dilution of organic and inorganic impurities in the air. It plays, however, a very important part in the removal of excessive moisture. Watery vapour, it must be remembered, is given off into the air, not only in respiration, but also largely by artificial lights, and not a little of the discomfort attending vitiated atmospheres is due to the large amount of their contained moisture. Both de Chaumont and Billings have laid special stress upon the importance of humidity in connection with ventilation. The former says that an increase of one per cent. of humidity has as much influence on the condition of an air-space, when judged of by the sense of smell, as a rise of 4·18 degrees of temperature in Fahrenheit's scale, equal to 2°·32 C., or 1°·86 R. Our everyday experience confirms this.

While 73 per cent., at a temperature of from 60° F. (15°·6 C.) to 70° F. (21°·1 C.), may be taken provisionally as a standard of humidity for climates like our own, in drier climates, like America, the standard or mean percentage of moisture may be as low as 30 or 40. In Germany, 50 per cent. is looked upon as an average humidity, whilst in England this would indicate an uncomfortably dry atmosphere.

METHODS BY WHICH THE NECESSARY QUANTITY OF FRESH AIR CAN BE SUPPLIED.

This subject is largely an engineering problem, and involves the consideration of certain preliminary matters, especially facts relating to cubic space and the various forces concerned in ventilation.

Cubic Space.—This is an important factor in ventilation in some cases, while in others it is of but secondary value. Sufficient has been said in the preceding pages to show that the hurtful matters in the air of an occupied room are constantly and equably produced, uniformly diffused, and fairly represented by the carbon dioxide present. It has further been explained that 0·2 of CO_2 per 1000 of air, in round numbers, may be taken as the maximum amount of impurity admissible in a properly ventilated air space. Adopting, then, this standard as the measure of the permissible maximum of impurity, the next point to be determined is the quantity of pure external air which should pass through the air of a room, vitiated by respiration, per head per hour, in order to keep the carbon dioxide at this ratio, assuming a general average of 0·6 of a cubic foot per head per hour

* F. Smith: *Veterinary Hygiene*, London, 1887; also *Journal of Physiology*, vol. xi. 1890.
† Dammann: *Die Gesundheitspflege landwirtschaftlicher Haussaugetiere*, Berlin, 1892.

to be given out. This question we have seen to be answered in terms of a standard of 3000 cubic feet.

The position of the inlets is a matter of some difficulty. If there are several, they should be, of course, equally distributed through the room, so as to ensure proper mixing of the air. They should not, however, be placed too near an outlet, or the fresh air may at once escape; theoretically, their proper place of entrance is at the bottom of the room, but if so, the air must in this climate be warmed; no person can bear the cold air flowing to and chilling the feet. The air can be warmed easily in various ways, viz.:—

(*a*) The air may pass through boxes containing coils of hot-water pipes, or (in factories) of steam pipes. This is one of the best modes of warming. The coils may be close to the outside wall, or in the centre, or, in hospitals, in boxes under the beds communicating with the exterior air, and opening into the ward.

(*b*) The air may pass into air-chambers behind or round grates and stoves, and be there warmed, as in the stove contrived by Galton, or the air may be warmed in a tube passing through a stove, as in George's Calorigen, or by the method of Bond's Euthermic stove.

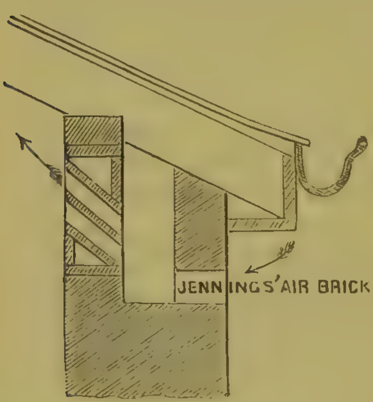


Fig. 9.

If the air cannot be warmed, it must not be admitted at the bottom of the room; it must be let in above, about 9 or 10 feet from the floor, and be directed towards the ceiling, so that it may pass up and then fall and mix gradually with the air of the room. The Barrack Commissioners have adopted this plan with half the fresh air brought into a barrack-room. The other half is warmed.

In towns or manufacturing districts the air is so loaded with particles of coal or other dust that it must be filtered. Nothing answers better for this than muslin or thin porous flannel, or paperhangers' canvas, spread over the opening, which then should be made larger. This covering can be moistened if the incoming air be too dry. The use of air-washing screens at the intakes has been very generally employed of late years in the ventilation of hospitals and public buildings. The practical application of these air-filters constitutes a material advance in ventilation methods.

Among the many devices for inlets of fresh air, the simplest plan is that of Hinckes Bird. The lower sash of a window is raised by means of an accurately fitting block of wood, whereby a corresponding space is left between the upper and lower sashes in the middle of the window, through which the external air passes, and, being directed upwards, curves gently into the room without perceptible draught. With the same idea, others have proposed double panes of glass, an open space being left at the bottom of the outer and at the top of the inner one.

Perforated sashes are made by boring holes into the lower part of the upper sash; the air enters vertically, but being divided up into small streams no draught is perceptible. This plan considerably weakens the window frame.

Double windows constitute an excellent method for the admission of air. By opening the outer one at the bottom and the inner one at the top, a very efficient air-shaft is formed. Swinging windows are often employed as inlets, particularly in hospitals and large schools. They may be so arranged that the whole window swings on a centre pivot, thus offering a

very large inlet; or only the upper part of a window opens inwards like a valve, and thus directs the current up towards the ceiling.

Louvres or ventilators constructed on the principle of venetian blinds are a very common form of inlet. The louvres or strips of glass are connected together on to a frame, which, by a mechanical arrangement, can be opened or shut at will. Cooper's ventilator is merely a circular disc of glass, perforated with holes and attached by means of a pivot to a pane of glass similarly perforated. By rotating the disc, the holes in the pane and disc can be made to correspond or not as required.

Fig. 10.
Sheringham Valve.

Perforated or air-bricks, such as those of Ellison, consist of bricks which are pierced with conical holes, about $\frac{2}{10}$ths of an inch in diameter externally and $1\frac{1}{4}$ inch internally, depth $4\frac{1}{2}$ inches. A usual size is 9 by 3 inches, and the united area of all the several openings in one brick is about $11\frac{1}{2}$ square inches. Another common size is 10 by 6 inches, with an open area of about 24 square inches. The air blown in from the narrow to the wide end of the openings is so distributed as to be imperceptible as a draught in a room. These bricks are best placed just behind, and concealed by, the skirting-board. Jennings's air-brick (Fig. 9) is another form of these inlets. These are more usually placed in the walls near the ceiling, and differ from Ellison's bricks in that the air is first led into a small chamber, where the dust can deposit. From this "dust-trap" the air passes through louvres into the room.

Steven's drawer ventilator is very like a drawer, with its back or end most remote from the handle absent. This drawer is made to fit into a hole in the wall; when it is shut there is, of course, no air-current, but when pulled open, the air enters freely, and impinging against the front, is given an upward direction.

The Sheringham valve is a great improvement on this; the air passes through a perforated brick or iron box inserted in the wall close to the ceiling of the room. The current of inflowing air is then directed upwards by a valve opening, which can be closed, if necessary, by a balanced weight (Fig. 10). The size of the internal opening is, in the usual sized valve, 9 inches by 3, and the area is 27 inches. This is somewhat larger than the outside area, and the velocity of the entering air is accordingly lessened. The wind blows through them, and the movement is therefore variable. They are often outlets; it will, in fact, depend upon circumstances whether they are inlets or outlets. Very little draught is, however, caused by them, unless with a high wind; on the whole, they are the best inlets of this kind.

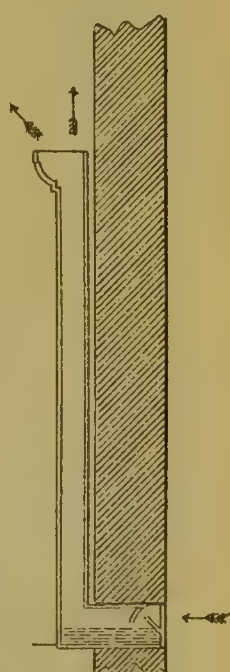


Fig. 11.
Tobin's Tube.

An open iron frame of the size of a brick, covered with perforated zinc, and with a valve to close it if necessary, is a still simpler plan, and distributes the air efficiently, provided the perforations be kept clean. Boyle used a round plate working on a screw, which can be brought nearer or farther from a corresponding opening in the wall; the air entering strikes on the plate, spreads circularly over the wall, and is then drawn gently into the room. The tubes proposed by Tobin (Fig. 11) provide for the introduction of air from the outside at the floor level and then up a vertical tube, about 6 feet in height; this gives a vertical direction to the current, which is retained for several feet further before

it begins to spread and descend. The action of such a tube is, of course, much affected by the direction of the wind, and in some instances it is reversed altogether. The method is, however, useful in most cases, particularly for introducing air into places which could only be reached with difficulty by other means. In some forms there is an arrangement for washing the air and arresting impurities.

The Tobin tubes are not very suitable for ordinary houses and dwelling-rooms, as they are difficult to keep clean, and often became clogged up with cobwebs, dirt, and dust. They, moreover, do not readily become or act as outlets when occasion requires, which, being a conspicuous feature of the Sheringham valve, renders that form of ventilating agent practically the most convenient for everyday application.

Position and Varieties of Outlets.—The place for the outlets is a most important consideration, as it will determine in great measure the position of the inlets. If there are no means of heating the air passing through them, they should be at the top of the room; if there are means of heating, they may be at any point. If not artificially warmed, the highest outlet tube is usually the point of greatest discharge, and sometimes the only one. In the absence of artificial heat, they should be placed at the highest point of the room; should be enclosed as far as possible within walls, so as to prevent the air being cooled; should be straight and with perfectly smooth internal surfaces, so that friction may be reduced to a minimum. In shape they may be round or square, and they may be fitted above with some apparatus which may aid the aspirating power of the wind and prevent the passage of rain into the shaft.

The causes of down-draught in outlet tubes are these:—the wind forces down the air, rain gets in, and by evaporation so cools the air that it becomes heavier than the air in the room; or the air becomes too much cooled by passage through an exposed tube, so that it cannot overcome the weight of the superincumbent atmosphere; or another outlet shaft with greater discharge reverses the current. Arrangements should be made to distribute the down-draught, if it occurs; flanges placed at some little distance below, so as to throw the air upwards again before it mixes with the air of the room, or simple contrivances of a similar kind may be used. Valves should be also fixed to lessen the area of the outlet when necessary. If there are several outlet tubes in a room, all should commence at the same distance from the floor, be of the same height, and have the same exposure to sun and wind.

Simple ridge openings may be used in one-storeyed buildings with slanting roofs; they ventilate most thoroughly, but snow sometimes drifts in. Rain may be prevented entering by carrying down the sides of the overhanging ridge for some little distance. A flange placed some little distance below will throw any down-draught towards the walls.

With artificial warmth, the discharge of outlets is much more certain and constant. The ordinary chimney with an open fire is an excellent outlet, in fact it is so good that, in dwelling-houses, provided there are proper inlets, no other outlet need be made, except, however, when gas is used. When rooms are large, and more crowded, other outlets are necessary; the heat of the fire may be further utilised by shafts round the chimney, opening at the top of the room, or, in other words, by surrounding the smoke-flue with foul-air shafts.

Gas, if used, may be made to warm an outlet tube, both to carry off the products of combustion and to utilise its heat. Probably a better arrangement would be to make the ventilation independent of the lighting, and to enclose the gas-lights, so that only so much air is supplied to the gas as is

required for its combustion; this may be drawn either from the room or separately from the outside.

There will seldom be any difficulty in arranging the inlets and outlets, and in obtaining a satisfactory result, if these principles are borne in mind, viz., to have the fresh air pure, to distribute it properly, and to adopt every means of securing the outlets from cold, or artificially warming them, and of distributing the air, which, in spite of all precautions, will occasionally pass down them. In hot climates, when outlet shafts are run up above the general level of the building, it would be of advantage to make them of brickwork, and to colour them black, so that they may absorb and retain heat.

Frequently so-called ventilating gas-lights are used as outlets, in which the products of combustion, after being collected by means of a cover or bell-glass, are carried off by a tube which is itself often contained in a larger one. Owing to the heating of the inner tube, the space surrounding it and between it and the outer one acts as an extracting shaft for foul air. In theatres and other public buildings advantage is taken of this method by using the sunlight gas-burners, which, in addition to lighting the building, act as extraction shafts for removing the polluted air. To guard against possible down-draught, the shaft or tube should be surmounted by either a cowl or be provided with a horizontal plate of talc, which, threaded on a central pin only, and resting on a seat, is lifted up by any upward pressure, but closes the channel under the slightest pressure from above.

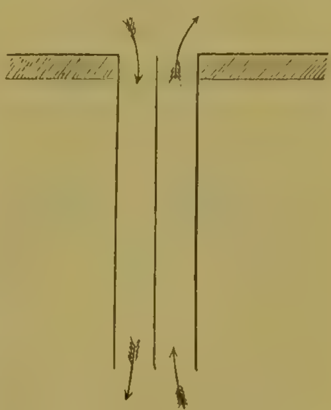


Fig. 12.—Watson's Tube.

Another arrangement, known as Arnott's valve, is designed to act as an outlet for foul air. It is usually placed in the wall of a room near the ceiling, so as to open into the chimney. The valve is so arranged as to swing towards the chimney, when the pressure or draught of the air is from the room to the chimney; but when the pressure is greater from the chimney into the room, the valve closes, and thus prevents the escape of smoke or air from the chimney. These valves are sometimes objectionable, owing to the noise they make.

A single tube has been sometimes used for inlet and outlet, a double current being established. This is, however, a crude plan, as there are no means of distributing the air, and as the intermingling of the current and the friction of the meeting air is sometimes so great as to impede, or even for a time stop, the movement. To avoid these inconveniences, Watson proposed to place a partition in the tube (Fig. 12), and Mure suggested the use of a double partition running from corner to corner, so as to make four tubes. In these tubes, accidental circumstances, such as the sun's rays on one side, the wind, the fire in the room, &c., will determine which is outlet and which is inlet. They are so far better than the single tube that the partition divides the currents and prevents friction, but there is the same irregular action and changing of currents from accidental circumstances, so that the direction of the currents and their rate are variable. The distribution of the entering air is also not good.

Much better than these plans is M'Kinnell's circular tube. It consists of two cylinders, one encircling the other, the area of the inner tube and encircling ring being equal. The inner one is the outlet tube; it is so because the casing of the other tube maintains the temperature of the air in it; and

it is also always made rather higher than the other ; above it is protected by a hood, but if it had a cowl it would be better. The outer cylinder or ring is the inlet tube ; the air is taken at a lower level than the top of the outlet tube ; when it enters the room it is thrown up towards the ceiling, and then to the walls by a flange placed on the bottom of the inner tube ; the air then passes from the walls along the floor towards the centre of the room, and upwards to the outlet shaft (Fig. 13). Both tubes can be closed by valves. If there is a fire in the room, both tubes may become inlets ; to prevent this the outlet tube should be closed ; if doors and windows are open, both tubes become outlets.

The movement of air by this plan is imperceptible, or almost so ; it is an admirable mode for square or round rooms, or small churches, but for very long rooms it is less adapted. It would be advisable to make the outer ring of these tubes larger, as the friction to be overcome is about double that of the inner tube.

On much the same principle, ventilating cornices are made, which consist of a double channel of perforated metal ; by the lower channel cold fresh air is brought into a room, while by the upper one the fouled air is carried to the chimney or other outlet. Analogous to this plan is that of carrying along a cornice of a room, on three sides, a perforated inlet tube, while on the fourth side is a similarly perforated outlet tube. In other cases, a fairly good cross ventilation can be secured by means of a series of transverse ventilating boxes or tubes placed at regular intervals close to the ceiling. These, running across the room from wall to wall, open into the outer air at each end by an air-brick. The sides of these tubes are made of perforated zinc, and to prevent the wind blowing right through, they are stopped or blocked in the centre by a partition. According as to whether the wind blows from one side or the other, so one half becomes an inlet for fresh air, which diffuses gently into the room through the perforations, while the other half acts as an outlet for the fouled air.

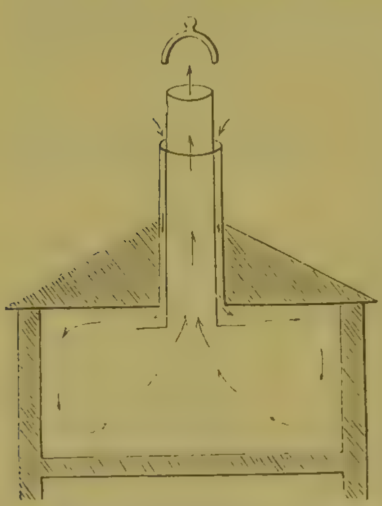


FIG. 13.—M'KINNELL'S TUBE.

Artificial Ventilation.—The chief agencies by which ventilation is artificially secured are heat, steam-jets, pumps and fans or wheels ; according as to whether these various means act by drawing the air out of a building or room, or whether the air is driven in so as to force out that which is already in the room, so is any given scheme of mechanical ventilation spoken of as being one by extraction methods or one by propulsion.

Extraction by Heat.—The common chimney is a well-known example of this. There is a constant current up the chimney, when the fire is burning, in proportion to the size of the fire and the chimney. The usual current up a common sitting-room chimney, with a fair fire, is, as measured by an anemometer, from 3 to 6 feet per second. A very large fire will bring it up to 8 or 9 feet. The movement caused by a kitchen or furnace fire is, of course, greater than this.

With an ordinary fire, a chimney gives a discharge sufficient for four or five adults ; if more than this number habitually occupy a room, another outlet must be provided. When the air enters equably, and is well distributed, the movement of air is from the inlets gently towards the fireplace ;

there is also said to be a movement from above the fireplace, along the ceiling and down the walls, and then along the floor to the chimney. As the current up the chimney is so great when the fire is lighted, all other openings in a room, if not too many, become inlets ; and, in this way, down-draughts of air may occur from tubes intended as outlets. There is no remedy for this ; and if too much enters, the outlets must be more or less closed.

If the room be without openings, so that no air can reach the fire, air is drawn down the chimney, and a double current is established, by which the fire is fed. The down-current coming in puffs is one cause of smoky chimneys, and may be at once cured by making an inlet. The chimney and fire is a type of a number of other similar modes of ventilation by extraction.

The ventilation of mines is often carried on by lighting a fire at the bottom of a shaft (the upcast or return shaft), or half a shaft, if there be only one. The air is drawn down the other or downcast or intake shaft, or half the shaft, and is then made to traverse the galleries of the mine, being directed this way or that by partitions. Double doors are used, so that there is no back or side rush of the air. The current passes through the upcast shaft at the rate of from 8 to 10 feet per second ; it flows through the main galleries at the rate of from 4 to 6 feet per second, or even more, and from 1000 to 2000 cubic feet per head per hour are supplied in good mines. In fire-damp mines much more than this is given, even as much as 6000 cubic feet per man per hour.

If a furnace be used to ventilate a fiery mine, it is usual to bring special air to support combustion through a separate channel from the outer air, in order to prevent the mine air coming in contact with the furnace flames.

Though this system of ventilating by furnaces is still used in some collieries, it cannot compete, except at great depths, with mechanical methods. Speaking roughly, the useful effect from furnaces rarely exceeds 5 per cent. of the actual energy given out by the fuel consumed ; the maximum power being the discharge of about 1000 cubic feet per minute per foot area of the upcast shaft.

In large buildings the same plan is often used ; a chimney is heated by a fire at the bottom, and into the bottom of this shaft, close to the fire, run a number of tubes coming from the different rooms. Several French and English hospitals, and many other buildings, are ventilated in this way, Reid for some years ventilated the Houses of Parliament in the same manner, and so powerful was his up-draught that he could change the entire air in the building in a few minutes.

In dwelling-houses it has been proposed to have a central chimney, into which the chimneys of all the fires shall open, and to surround this with air-shafts connected with the tops of the rooms. It is supposed that, if other inlets exist, there will be a current both up the chimney and up the shaft running beside it. In all these cases it is necessary that the workmanship shall be very exact, so that air shall not reach the extracting shaft except through the tubes.

On the same principle some men-of-war are now being ventilated. The funnel and upper part of the boiler, and, as far as possible, all the steam apparatus, are enclosed in an iron casing, so that a space is left of some 3 or 4 feet between the casing and the funnel. When the fires are lighted, there is, of course, a strong current up this space ; to supply this the air is drawn down through all the hatchways towards the furnace doors. The temperature of the stokehole is reduced from 130° or 140° F. to 60° and 70°, and the

draught to the fires is so much more perfect that more steam is obtained from the same amount of fuel.

Sometimes, instead of a fire at the bottom of the chimney, it is placed at the top; but this is a mistake, as there is a great loss of heat from the immediate escape of the heated air; the proper plan is to heat, as much as possible, the whole column of air in the chimney, which can only be done by placing the fire below. Sometimes, as in Jebb's method for prison cells, the shaft is too short for the work it has to do.

Frequently, instead of a furnace, heat is obtained for extraction shafts by means of accelerating coils containing either steam or hot water, or even hot oil. In other cases, instead of a fire or hot-water coils, lighted gas is used to cause a current, and if the gas can be applied to other uses, the plan is an economical one. In theatres, the chandeliers have long been made use of for this purpose. It is calculated that each cubic foot of gas burnt is capable of extracting 3000 cubic feet of air; thus twenty burners, each consuming 5 feet of gas hourly, will withdraw 300,000 cubic feet of air, corresponding to the complete renewal six times in the hour of the air of a hall 100 feet × 25 feet × 20 feet. Though the extracting power of gas under suitable tubes is undoubtedly large, its practical value as a ventilating agent may be overrated, as generally its special flue is in a position most unfavourable for general ventilation. This is particularly the case when the gas is intended to be both an illuminant and a means of ventilation, as in public halls, where the air must be very impure before a central chandelier is effective in removing impurity.

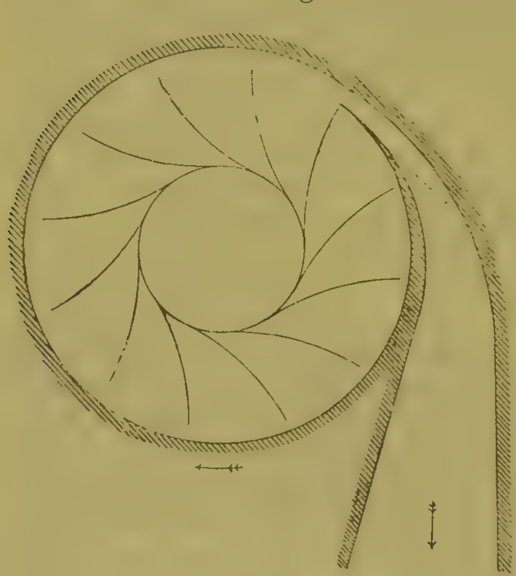


FIG. 14.—GUIBAL'S FAN.

Extraction by the Steam-jet.—The moving agent here is the force of a steam-jet, which is allowed to pass into a chimney. The cone of steam sets in motion a body of air equal to 217 times its own bulk. Tubes passing from different rooms enter the chimney below the steam-jet, and the air is extracted from them by the strong upward current. This plan is best adapted for factories with spare steam. It was employed for some time in the ventilation of the House of Lords, but was finally abandoned.

In some collieries the steam-jet has been tried with great success; in principle the action of a steam-jet is similar to the production of a head by the passage of wind over an aperture, that is, by a lowering of pressure in the vicinity of the aperture. Steam-jets are unsuited for exhausting large quantities of air at low pressures.

Extraction by Pumps.—This method is employed at some collieries and was used also at the works on the St. Gothard Tunnel. The air-pumps in the St. Gothard works were cylinders hung at each end of a rocking beam, which alternately dipped into water-tanks. The tops of the cylinders were fitted with outlet valves, while the space to be ventilated was connected by pipes and inlet valves with the cylinders. Each time the cylinder rose, it filled with air from the tunnel, which was expelled through the valves in the top when it fell. They worked efficiently with a water-gauge of 6 inches.

[*Extraction and Propulsion by Fans.*—These are very largely used in tunnels and collieries. A fan ventilator is nothing but a wheel formed by a number of vanes attached to an axle. When the wheel is rapidly rotated, air is carried along by the vanes, finally leaving the tips of the vanes tangentially with a velocity practically equal to that of the vane tips. As the wheel rotates, the air tends to move from the axis to the circumference, causing thereby a lessening of pressure at the axis.

One of the best of these fans is Guibal's (Fig. 14), which is enclosed in a circular cover, with openings at the axle and an opening at the periphery which leads into a tube along which the air is discharged. By placing the axis of the wheel excentrically with regard to the circle of the enclosing case, an appreciable space is formed, between the periphery of the revolving vanes and the cover, gradually increasing up to the discharging tube. This arrangement materially saves the kinetic energy of the wheel by saving loss of power in the production of eddies. When working, air is drawn through the apertures near the axle, and driven into and along the tube. In the best forms of these fans the size of the delivery aperture can be altered by means of a sliding door, the aperture itself is trumpet-shaped, and the vanes are so shaped that, though tangential to the aperture at the axle, they are at right angles to the periphery at the tip; this enables the air to slide on to the vanes without loss of energy in eddies.

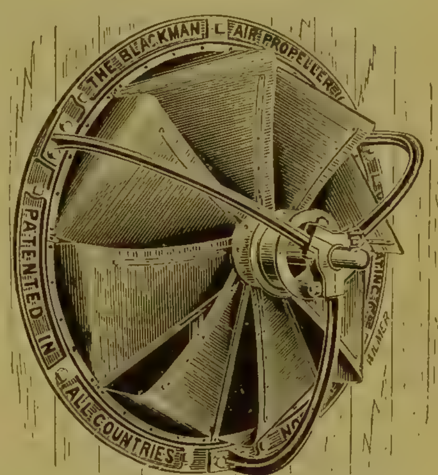


FIG. 15.—BLACKMAN'S FAN.

The Blackman Air-propeller is a kind of fan (Fig. 15) much used in ventilation. It is claimed for this agent that the larger sizes will give 12,000 cubic feet and the smaller ones 6000 cubic feet of air per minute for each horse-power expended in driving them. This estimate is based upon there being no resistance against the air except that from the machine itself.

In the ventilation of mines, the resistance to the movement of the air due to friction from the gallery surfaces, abrupt turns, expansions and contractions of ducts, and from eddies is often very great, so much so that a large part of the power employed to produce air-currents is needed to overcome this resistance. The friction increases in direct proportion to the area of the surface and as the square of the velocity of the current.

The use of blowing machines for ventilation has been known since 1734, when Desaguliers invented a fan or wheel enclosed in a box. The fan, if small, is worked by hand as in the machine largely used in India, under the name of the Thermantidote. Larger fans are worked either by horses, by electricity, or by steam-engines. The amount of air delivered can be told by timing the speed of revolution of the extremities of the fan per second, or per minute; the effective velocity is equal to $\frac{3}{4}$ths of this, and this is the rate of movement of the air. If the section area of the conduit be known, the number of cubic feet discharged per second, minute, or hour can be at once calculated.

In the present day, Root's blower, a machine worked by rotating pistons, is largely used. In principle it is a revolving pump, in which two pistons, each shaped like a figure of 8, are worked on parallel axles inside a box with two openings. As the pistons rotate, the air is drawn in at one opening and driven out at the other. In all machines of this type it is evident that a

definite volume of air is transmitted at each stroke, and knowing this volume from measurements of the machine, the actual delivery per second is readily worked out from the speed of revolution, and whatever head is needed to drive that volume will be supplied from the source of power which drives the fan.

Fans are well adapted for those cases in which a large amount of air has to be suddenly supplied, as in crowded music-halls and assembly-rooms. Many public buildings are ventilated efficiently in this way, the air being drawn in usually from the basement, filtered and cooled by passing through moist canvas screens and warmed, if necessary, by passage over radiators containing either steam or hot water.

It will be readily understood that any given scheme of ventilation need not, necessarily, be limited to either extraction or propulsion, but may be carried out by a combination of both methods.

Comparative Value of Ventilation Methods.—In endeavouring to compare extraction methods with those of propulsion in attempts to ventilate mechanically, we find that there are some objections to both. When extraction of air is produced by fire and hot-air shafts, there is often inequality of draught due to the impossibility of keeping the fire at a constant heat. Another difficulty arises from the inequality of the movement from different rooms. From rooms nearest the shaft, and with the straightest connecting tubes, there may be a strong current, while from distant rooms the friction in the conduits is so great that little air may pass. The greatest care is therefore necessary in calculating the resistance, and in apportioning the area of the tubes to the resistance. This plan is, indeed, best adapted for compact buildings. Occasionally, if the friction be great, from too small size or the angular arrangement of the conduits leading to the hot shaft, there may be no movement at all in the conduits, but a down-current to feed the fire is established in the shaft itself.

The possibility of reflux of smoke, and perhaps of air, from the shaft to the rooms is another objection of some weight, to which must be added the impossibility of properly controlling the places where fresh air enters. It will flow in from all sides, and possibly from places where it is impure, as from closets, &c. ; in spite of every care it is difficult to bring air under complete control—it will always press in and out at the point of least resistance.

The advantages of ventilation by propulsion are its certainty, and the ease with which the amount thrown in can be altered. The stream of air can be taken from any point, and can, if necessary, be washed by passing through a thin film of water, or through a thin screen of moistened cotton, and can be warmed or cooled at pleasure to any degree. In fact, the engineer can introduce into this operation precision and full control.

The disadvantages are the great cost, the chances of the engine breaking down, and some difficulties in distribution. If the air enter through small openings at a high velocity, it will make its way to the outlets without mixing. The method requires, therefore, great attention in detail.

As to the relative value of natural and artificial ventilation, we find circumstances differ so widely that it is impossible to select one system in preference to all others. In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation with such powers of extraction as can be obtained by utilising the sources of warming and lighting, is the best. Incessant movement of the air is a law of nature. We have only to allow the air in our cities and dwellings to take share in this constant change, and ventilation will go on uninterruptedly without our care.

In some circumstances, however, as in the tropics, with a stagnant and warm air; and in temperate climates, in certain buildings where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used. So much may be said both for the system of extraction and propulsion under certain circumstances, that it is impossible to give an abstract preference to one over the other. In fact, it is evident that the special conditions of the case must determine the choice, and we must look more to the amount of air, and the method of distribution, than to the actual source of the moving power. But in either case the greatest engineering skill is necessary in the arrangement of tubes, the supply of fresh air, &c. The danger of contamination of air as it passes through long tubes, and the immense friction it meets with, must not be overlooked. The cost of the various plans will depend entirely on circumstances, the nature of the building, the price of materials, coal, &c. On the whole, the plans of ventilating and warming by hot-water pipes are cheaper than the method of propulsion by means of a large fan; but the latter gives us a method which is more under engineering control, and is better adapted for hot climates when it is desired to cool the air. By means of damp canvas air-screens or filters placed at both inlets and outlets, cleansed, tempered and humidified air may be propelled through narrow wedge-shaped openings in the ceilings, and then, by means of a simple form of spreader, be evenly distributed through buildings. This arrangement has already been successfully applied to several hospitals, and certainly seems the proper plan, as it not only ensures the delivery of clean air, but also purifies that emitted from the building.

It must not be overlooked that the specific gravity of vitiated air, as compared with pure air, is often as important as friction in hindering ventilation action. Usually the specific gravity of foul air is greater than that of fresh air; for instance, taking pure air as unity, the gravity of air containing 0·8 part of carbon dioxide per 1000 would be 1·0016, while that of air fouled by organic vapours would be greater still. This explains why contaminated air tends to cling or hang about particular parts of rooms, or, if there are no air currents, smells are so often apt to flow down towards basements of houses from the upper storeys. It is obvious that in such cases calculations based upon the movements of absolutely pure air may be considerably in error.

Natural Ventilation.—Of all the methods of natural ventilation, the simplest and most obvious is that of more or less open doors and windows; but this arrangement, except in the warmest summer weather, causes draughts, and is unpleasant. To secure adequate perflation, all windows should, if possible, be placed on opposite sides of a room, while, too, each of such windows should be made to open at the top. Owing to air flowing against the body, at or even slightly above the temperature of a room, causing a sensation of cold or draught, it is necessary for comfort that air should be introduced into and removed from inhabited rooms at those parts where it will not give rise to sensible draughts. In the large majority of houses, even in these days, ventilation arrangements are either of the most crude and haphazard kind, or else absolutely wanting. The greater number of living-rooms depend for their supply of fresh air upon just so much as can find its way in through doors, windows, or through cracks and crevices around and under doors and windows, or even through the floor; and for the escape of foul air, upon what goes up the chimney, if a fire be alight, or what can get out through doors and windows; the general result being that either the chamber is so cold and draughty that no one can live comfortably

in it, or so hot, close, and stuffy that health is affected. All ventilation methods aim at avoiding these results, by providing, in the first place, *inlets* or means of entrance for the fresh air, and *outlets* or means of escape for the impure air.

Total Size of all the Special Openings, whether intended for Inlets or Outlets.—As the movement of air increases with temperature, the precise size of the ventilating apertures can only be fixed for a certain given temperature; and as the efflux of hot air increases with the height of the column, supposing the temperature is equal throughout, a different size has also to be fixed for different heights. This causes a difficulty in fixing the proper size for ventilating openings in the case of natural ventilation, because the conditions are so variable.

The theoretical size for any required change of air, supposing the conditions are constant, can be obtained by the use of the following formula, suggested by de Chaumont :—

$$\frac{D}{200f(\sqrt{h(t-t^1)\times 0{\cdot}002})}=\text{I or O.}$$

Where D = delivery per hour in cubic feet; 200 is a constant; f is the coefficient of friction; h is the height of the heated column of air; t its temperature; t^1 that of the outer air; 0·002 the ratio of expansion of air for each degree F.; I indicates inlet, O indicates outlet, both in square inches; while I and O combined are often written as ϕ. A converse formula to the foregoing is useful to find the delivery per hour, under conditions h, t, and t^1, and when the area of the inlet or outlet is known; it reads thus,

$$200f(\sqrt{h(t-t^1)\times 0{\cdot}002})O=D.$$

The different expressions for time and space require a factor 200 or 100, which is thus obtained: $\frac{\text{Seconds in an hour}}{\text{Square inches in a square foot}}=\frac{3600}{144}=25$, which, multiplied into $\sqrt{2g}$ or 8, where $g=32{\cdot}18$, gives a constant 200 for inlets or outlets only, and consequently 100 for inlets and outlets combined.

Experience shows how impossible it is to fix any size which shall meet all conditions, even if the influence of wind could be completely excluded, which is impossible. The only way is to adopt a size which will meet most cases, and supply means of altering the size according to circumstances. In this country, a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt. Moreover, the size must be in part dependent on the size of the room, because in a small room with many people it is impossible to have the size so great as it would be if each person's area of ventilation opening were 48 square inches, unless some portion of the air were warmed.

It is desirable to make each individual inlet opening not larger than 48 to 60 square inches in area, or enough for two or three persons; and to make the outlet not more than 1 square foot, or enough for six persons. Distribution is more certain with these small openings.

Position and Varieties of Inlets.—As a rule, the inlet tubes should be short, and so made as to be easily cleaned, otherwise dirt lodges, and the air becomes impure. Inlets should not be large and single, but rather numerous and small (from 48 to 60 inches superficial), so that the air may be properly distributed. They should be conical or trumpet-shaped where they enter the room, as the entering air, after perhaps a slight contraction,

spreads out fan-like, and a slight back current from the room down the sides of the funnel facilitates the mixing of the entering air with that of the room. To lessen the risk of immediate down-draught they should turn upwards, if they are placed above the heads of the persons. Externally the inlets should be partly protected from the wind; otherwise the wind blows through them too rapidly, and, if the current be strong, draughts are felt; an overhanging shelf or hood outside will answer well. Valves must be provided to close partially the openings if the wind blow in too strongly, or if the change of air be too rapid in cold weather. If covered with wire gauze, this must be frequently cleaned.

Sometimes an inlet tube must be carried some distance to an inner room, or to the opposite side of a large room which is unprovided with cross-ventilation. In this case the heat of the room so warms the tube that the wind may be permitted to blow through.

When we come to inquire whether there is any minimum space through which the fresh air has to pass, we find that this will entirely depend on the rate at which air can be taken through the space without the movement being perceptible or injurious, and the cubical capacity is of consequence chiefly in so far as it affects this condition. The larger the air space, the less is the necessity for the frequent renewal of air, and the less the chances of draught. Thus a space of 100 cubic feet must have its air changed thirty times in an hour, if 3000 cubic feet of air are to be given, while the space of 1000 cubic feet need only have it changed three times in an hour for an equal ventilation.

When the most perfect mechanical means are employed, the air of even a small air space can be changed sufficiently often without draught. Thus, in Pettenkofer's experimental room at Munich, the air space was 424 cubic feet, and 2640 cubic feet were drawn through by a steam-engine in an hour without perceptible movement; in other words, the change was six times per hour nearly. With the best mechanical contrivances, and with disregard of cost, we are therefore certain that a cubic space of 600 feet would be sufficient, and there is every probability that engineers could ventilate even a smaller space without perceptible movement.

But if the mechanical contrivances are of an inferior kind, and particularly if natural ventilation is used, the difficulties of ventilating a small space are considerable, and are caused not so much by the rate of movement of the greater part of the air in the room as by the rate at the openings, where the fresh air comes in very quickly and causes currents in the room. Suppose, for example, a space of 500 cubic feet be occupied by one person, who has to be supplied with 3000 cubic feet in an hour; if the inlet opening be 12 square inches, the rate of movement through it would be 10 feet per second, or nearly 7 miles per hour; if 24 square inches, it would be 5 feet, or about 3·4 miles per hour. In either case, in such a small room, the air could not be properly distributed before reaching the person, and a draught would be felt. If instead of 500 cubic feet of space, 1000 be given, the problem is easier, for the small current of fresh air mixing with the larger volume of air in the room is more easily broken up, and the inmate being further from the opening, the movement is less felt. The question, in fact, turns in great measure on the power of introducing the air without draught.

If the renewal of air is carried on by what is termed natural ventilation, under the ordinary conditions of this climate, a change at the rate of six times per hour, as in Pettenkofer's room, could not be attempted. Even five times per hour would be too much; for, in barracks with 600 cubic feet per head, the rooms are cold and draughty, when anything approaching

to 3000 cubic feet per head per hour are passing through ; that is, a change of five times per hour for each 600 cubic feet of air space. A change equal to three times per hour is generally all that can be borne under the conditions of warming in this country, or that is practically attainable with natural ventilation, and if this be correct, from 1000 to 1200 cubic feet should be the minimum allowance for the initial air space.

With good warming and an equable movement, which, however, are not always easy to get, there might be larger inlets, and therefore more easy distribution and a smaller initial air space. If the inlets are 48 square inches, the rate through them to supply a space of 500 cubic feet with 3000 cubic feet per hour would be only $2\frac{1}{2}$ feet per second ; and if, as should be the case in artificial ventilation, the inlet is 72 or 80 square inches in size, the rate would only be a little over $1\frac{1}{2}$ feet per second, which would be imperceptible even at the orifice. But there is an argument against a small cubic space, even with good mechanical ventilation, viz., that if anything arrests the mechanism for a time, the ratio of impurity from respiration increases much faster in a small than in a large space.

The warmth of the moving air influences the sensation of the persons exposed to it. At a temperature of 55° or 60° F., a rate of $1\frac{1}{2}$ feet per second (= 1 mile per hour nearly) is not perceived; a rate of 2 to $2\frac{1}{2}$ per second (1·4 and 1·7 mile per hour) is imperceptible to some persons ; 3 feet per second (2 miles per hour nearly) is perceptible to most ; a rate of $3\frac{1}{2}$ feet is perceived by all persons ; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature, or moist. If the air be about 70° F., a rather greater velocity is not perceived, while if it be still higher (80° to 90° F.), the movement becomes again more perceptible, and this is also the case if the temperature be below 40° F. If the air could be warmed to a certain point in a cold climate, or if the climate be warm, there may be a much more rapid current, and consequently a smaller cubic space might be given. The subject of ventilation is in cold climates connected inseparably with that of warming, for it is impossible to have efficient ventilation in cold weather without warming the air.

The amount of cubic space thus assigned for healthy persons is far more than most people are able to have; in the crowded rooms of the artisan class, the average entire space would probably be more often 200 to 250 cubic feet per head than 1000. The expense of the larger rooms would, it may be feared, be fatal to the chance of such an ideal standard being generally carried out ; but, after all, the question is, not what is likely to be done, but what ought to be done ; and it is an encouraging fact that in most things in this world, when a right course is recognised, it is somehow or other eventually followed.

So in the case of soldiers, the amount of authorised regulation space (600 cubic feet) is below the standard now given, but still the space is as much as can be demanded at present, as it has been found very difficult, without incurring greater expense than the country would bear, to give every man even the 600 cubic feet.

In the metropolitan lodging-houses 30 superficial and 240 cubic feet are allowed ; in the section-houses of the metropolitan police 50 superficial and 450 cubic feet are given. The Local Government Board allows 300 cubic feet for every healthy person in the dormitories of poor-houses, and from 850 cubic feet and upwards, according to circumstances, as far as 1200 cubic feet for each sick person. In the Poor-law schools 360 cubic feet are given per head. In Dublin, an allowance of 300 cubic feet is required in the

registered lodging-houses. While the theoretical requirement for a child in an elementary school is 400 cubic feet, and for a lad in a large public school 800 cubic feet, as minima, we find that few Education Authorities can allow more than 130 cubic feet. The Board of Education endeavour to secure at least 80 cubic feet and 8 square feet for each unit of average attendance in the infant schools, and 10 feet of floor area with a cubic space of about 125 feet to each child in other schools. According to the model bye-laws of the Local Government Board, 300 cubic feet are allowed in common lodging-houses for each person above 10 years, and 150 cubic feet for each person younger. Other customary amounts of cubic space per head are 1000 feet in middle-class houses, 500 in good secondary schools, and 212 in ordinary one-roomed houses.

For *sick persons* the cubic space should be more than for healthy persons. We are to remember that there are other impurities besides those arising from respiration and transpiration, and that immediate dilution and as speedy removal as can be managed are essential.

Very much the same considerations apply to sick as to healthy men, except that the allowance of air in all cases of acute diseases must be greater ; and, therefore, especially if natural ventilation be employed, the cubic space has to be enlarged also, to ensure good distribution without draught, for surface chilling must be carefully avoided.

Admitting that, in hospitals, a minimum of 4000 cubic feet of fresh air per patient per hour should be supplied, if the change of air is to be three times per hour, as the best available rate of movement, the cubic space must be about 1300 cubic feet. A consideration of another kind may aid in determining the question as regards sick men. In hospitals a certain amount of floor space is indispensably necessary ; first, for the lateral separation of patients ; secondly, for convenience of attendance. For the first object, the greater floor space the better ; and in respect of the second, experience shows that the *minimum* floor space for convenient nursing should be 72 square feet per bed. In a ward of 12 feet in height, this would give only 864 cubic feet for each patient, which is much too small.

Considering, however, the immense benefit to patients of pure air, and the practical experience of hospital physicians, it is very desirable not to fix the floor and cubic space of hospital wards at the minimum of what may suffice. The desire of most hospital physicians and surgeons is to obtain for their patients, if they can, a floor space of 100 to 120 square feet, and a cubic space of 1500 to 2000 cubic feet, and in this they are right.

It must be distinctly understood that a minimum of floor space must be insisted upon in all cases, not less than $\frac{1}{12}$th of the cubic space.

An idea prevails among many people that cubic space may take the place of change of air, so that, if a larger cubic space be given, a certain amount of change of air may be dispensed with, or less fresh air be required. This is quite erroneous ; even the largest space can only provide sufficient air for a limited time, after which the same amount of fresh air must be applied hourly, whether the space be large or small. Even in a space of 10,000 cubic feet per head, the limit of admissible impurity would be reached in a few hours, after which the same hourly supply of 3000 feet would be as necessary as in a space of 100 feet.*

The cubic space required for *animals* has not been examined very carefully. Certainly animals, notably pigs, sheep, horses and cattle generally

* This question is considered mathematically by Donkin in "Report of Committee appointed to consider the Cubic Space of Metropolitan Workhouses," Blue Book, 1867 ; also see Haldane on the "Air of Factories and Workshops," *Journal of Hygiene*, vol. ii. p. 431.

emit large quantities of marsh gas from the intestines. Our chief knowledge on this question is derived from Reiset's observations.*

An average-sized sheep vitiates 112 litres, or 3·9 cubic feet of air per hour; calves vitiate 154 litres or 5·4 cubic feet; moderate-sized pigs vitiate 166 litres or, say, 6 cubic feet of fresh air hourly; rabbits about 10 litres or 0·35 cubic foot; fowls 1 litre or 0·035 cubic foot; a dog of medium size, 23·5 litres or 0·83 cubic foot; a cat weighing 10 lb. spoils 17·8 litres or 0·6 cubic foot of fresh air per hour.

On the basis of respiratory impurity alone, we may reckon that calves and pigs vitiate the air rather more than a man does; about 10 sheep foul the air in the same degree as 8 men; while 14 rabbits or 140 chickens are equal to a man in this respect. As a matter of fact, these animals contaminate more air than stated above, because they are always associated with their own excreta. If we followed the rule for men, and gave one-third the quantity of air supplied per hour, this would give for horses and cattle from 3000 to 7000 cubic feet. This, however, is probably not necessary, because change of air can be carried on more freely than in human habitations, and animals cannot close ventilators as men will often do. A floor space of 100 to 120 square feet would probably be sufficient, giving a space of 1200 to 1800 cubic feet, according to the height of the building. If this could be secured, there is every probability that the results would be excellent. We might put the estimate roughly at 2 cubic feet of space for every pound avoirdupois the animal weighs, the floor space being not less than $\frac{1}{12}$th of the cubic capacity. Another rule might be to give 600 times the amount of air vitiated, which is practically the rule employed in the case of adult men; an adult man renders, we know, 5 cubic feet of air absolutely irrespirable every hour, and 600 times this or 3000 cubic feet per hour of fresh air is the generally recognised amount required to keep the air of a room in the highest degree of practicable purity.

Formerly, in the cavalry stables of the British army each horse had 1605 cubic feet and 100 square feet of floor space. At present the superficial area of army stables has been fixed as follows:—for the stall alone, 60 feet; for the stall and share of passage, 85 feet, in stables with two rows of stalls; in stables with a single row of stalls the superficial area of stall and passage is 99 feet. F. Smith considers that the stall alone should be 70 feet, and the stall and share of passage, 100. In the Army Horse Infirmaries the superficial area is to be 120 square feet, or 179 with share of passage, and cubic space 1900 feet; sick-boxes 182, and the cubic space 2000 feet per horse.

In the stables of cattle there is often excessive overcrowding, and it is well known that there is a vast amount of disease among them, which, however, is seldom allowed to go far, as they are sent to the butcher. Ballard, who paid great attention to the cattle plague in Islington, recommended that at least 1000 cubic feet should be allowed per animal.

Source and Distribution of Air supplied.—In order that the object of ventilation shall not be defeated, it is necessary that the air entering a room shall be pure. The air must be the pure external air, and not be derived from places where it has stagnated and taken up impurities; if it is drawn along passages or tubes, and through louvres or basements, these should be capable of inspection and cleansing. All delivering air-shafts should, if possible, be short and easily cleaned. This is an important rule, and should lead to the rejection of all plans in which the air-shafts are

* Reiset: "On the Physiology of Respiration in Animals," in Hoppe Seyler's *Physiolog. Chemie*, Bd. ii. p. 536, Berlin, 1879.

long and inaccessible. Several instances have occurred of air being distributed by costly appliances, but drawn from an impure source, or allowed to be contaminated on its passage. Instead of perforated bricks, there should be sliding panels, or hinged flaps, so that the tube may be easily reached. In towns it may be necessary to filter the air, which is often loaded with the products of combustion and other impurities.

The air may require to be warmed to 60° or 65° F., or cooled according to the season or locality. The warming in cold and temperate climates is a matter of necessity, as, if discomfort is caused by cold draughts, ventilation openings are certain to be closed. When the external temperature is low, the air supplied will often require to be moistened as well as warmed. This can be done either by injecting clean steam or water spray, or simply by exposing a water surface to the air. For these islands, a humidity of 75 per cent. is the most general requirement.

The distribution in the rooms should be perfect, that is, there should be uniform diffusion of the fresh air through the rooms. The best way of ascertaining this is to compare the amount of air utilised, as calculated from the observed carbon dioxide, with the actual movement of air, as measured with the air-meter. If the distribution is good, the two quantities ought not to differ materially. Much difficulty is found in properly managing uniform diffusion, and it requires careful arrangement of the various openings. The distributing plans should, if possible, prevent the chance of respired air being rebreathed, especially in hospitals. As the ascent of respired air is rapid, on account not only of its temperature, but from the force with which it is propelled upwards, the point of discharge for patients in bed should be above.

By some it has been argued that it is better that the foul air should pass off below the level of the person, so that the products of respiration may be immediately drawn down below the mouth, and be replaced by descending pure air. But the resistance to be overcome in drawing down the hot air of respiration is so great that there is a considerable waste of power, and the obstacle to the discharge is sometimes sufficient, if the extracting force be at all lessened, to reverse the movement, and the fresh air forces its way in through the pipes intended for discharge. This plan, in fact, must be considered a mistake. In the case of vapours or gases the proper place of discharge is above; but heavy powders, arising in certain arts or trades, which from their weight rapidly fall, are best drawn out from below. Finally, in determining the plan of ventilation of a room, the whole building must be treated as one system, and the plan of air circulation drawn out for the whole. It is useless having a system which is only workable in a room so long as all the doors are shut, if one of the conditions of the room being used is that the doors be frequently open. This is particularly necessary in ordinary dwelling-houses, and it practically amounts to saying that every outlet for air should be supplied with an adequate air inlet, so that there shall be no head between different rooms.

Forces concerned in Ventilation.—All ventilation methods are based either upon forces continually acting in nature, which produce what has been called natural ventilation; or upon forces set in action by man, which produce the so-called artificial ventilation. This division is convenient, but not strictly logical, as the forces which act in natural do so also in artificial ventilation to a certain extent. These forces are practically three, viz., diffusion, winds, and the difference in weight of masses of air of unequal temperature.

Diffusion.—As every gas diffuses at a certain rate, viz., inversely as the

square root of its density, there is a constant escape of any foreign gas into the atmosphere at large. From every room that is not air-tight Pettenkofer and Roscoe have shown that diffusion occurs through brick and stone, and it is probable that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. But ordinary plastered and papered walls reduce diffusion to a most insignificant amount. Through chinks and openings produced by imperfect carpentry the air diffuses fast, and Roscoe found that when he evolved carbon dioxide in a room the amount had decreased one-half from that cause, in ninety minutes.

The amount of purification produced by diffusion under ordinary circumstances is shown by observation to be insufficient ; and in addition, organic substances, which are not gaseous, but molecular, are not affected by it. As a general ventilating power, it is therefore inadequate.

Winds.—The action of wind is a powerful ventilating agent in various ways. If it can pass freely through a room, with open doors and windows, the effect it produces is immense. For example, air moving only at the rate of two miles an hour (which is almost imperceptible), and allowed to pass freely through a room 20 feet broad, will change the air of the room 528 times in one hour. No such powerful action as this can be obtained in any other way.

There are two objections to winds as ventilating agents by perflation.

(1) The air may be stagnant. In this country, and, indeed, in most countries, even comparative quiescence of the air for more than a few hours is scarcely known. Air is called " still " when it is really moving 1 or $1\frac{1}{2}$ mile an hour. The average annual movement of the air in this country is from 6 to 12 miles per hour ; but it varies, of course, greatly from day to day, and in different places.

(2) A much more serious evil is the uncertainty of the movement, and the difficulty of regulation. When the velocity reaches 5 or 6 feet per second, unless the air be warm, no one will bear it. The wind is therefore excluded, or, if allowed to enter directly through small openings, is badly distributed. Passing in with a great velocity, it forces its way like a foreign body through the air in the room, causing draughts, and escaping, it may be, by some opening without proper mixing. A current entering in this way may be measured for many feet.

But the wind acts in another way. A moving body of air sets in motion all air in its vicinity. It drives air before it, and, at the same time, causes a partial vacuum on either side of its own path, towards which all the air in the vicinity flows at angles more or less approaching right angles. In this way a small current moving at a high velocity will set in motion a large body of air.

The wind, therefore, blowing over the tops of chimneys, causes a current at right angles to itself up the chimney, and the unequal draught in furnaces is owing, in part, to the variation in the velocity of the wind. Advantage, therefore, can be taken of this aspirating power of the wind to cause a movement of air up a tube. The wind, however, may impede ventilation by obstructing the exit of air from any particular opening, or by blowing down a chimney or tube. This is, in fact, one reason of the failure of so many systems of ventilation ; they may work well in a still atmosphere, but the immense resistance of the wind has not been taken into account. At 3 miles an hour, the pressure of the wind is $\frac{3}{4}$ of an ounce on each square foot ; it is 1 ounce at $3\frac{1}{2}$ miles ; 2 ounces at 5 miles ; 4 ounces at 7 miles ; $\frac{1}{2}$ pound at 10 miles ; and 1 pound at 14 miles.

In some systems of ventilation the perflating power of the wind has

been used as the chief motive agent. In Egypt, wind is allowed to blow in at the top of the house through large funnels. This plan has been in use from time immemorial. This was the case in Sylvester's plan, which was used at Derby and Leicester fifty or sixty years ago. A large cowl, turning towards the wind, was placed in a convenient spot near the building to be ventilated—a little above the ground if in the country, or at some height if in a town. The wind blowing down the cowl, passed through an underground channel to the basement of the house, and entered a chamber in which was a so-called cockle-stove or calorifère of metal plates or water or steam pipes, by which the air was warmed. It then ascended through tubes into the rooms above, and passed out by a tube or tubes in the roof, which were covered by cowls turning from the wind. So that the aspiratory power of the air was also used. This plan is extremely economical, but the movement of the air is unequal, and it is difficult to regulate it. It has been proposed to place a fan in the tunnel to move the air in periods of calm, the plan then becomes identical in principle, and almost in detail, with the method of Van Hecke.

In the ventilation of ships wind is constantly used; and by wind sails, or by tubes with cowls turning towards the wind, air is driven between the decks and into the hold. In using wind in this way, the difficulty is to distribute the air so that it shall not cause draught. This is best done by bending the tubes at right angles two or three times, so as to lessen velocity, or by enlarging the channel towards the opening in the interior of the vessel, and by placing valves to partially close the tubes, if necessary, and by screens of wire gauze. If perforated plates or wire gauze are used, care must be taken to see that they are constantly kept clean, as they very soon get clogged with dirt. It should also be understood that the delay by friction through fine wire gauze is exceedingly great.

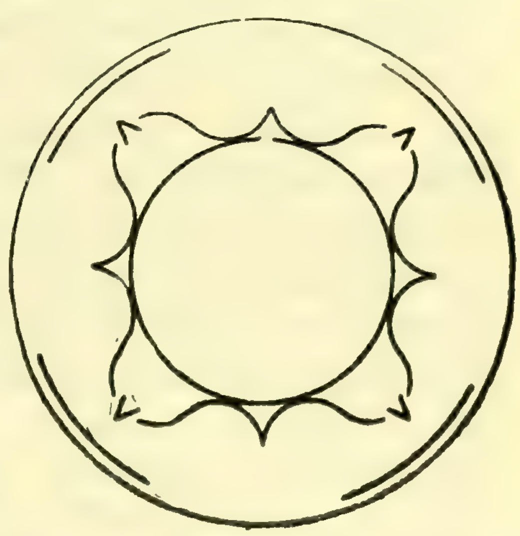


Fig. 16.—Sectional View of a Boyle's Ventilator.

In all cases in which the air of a room, as in a basement storey, or in the hold of a ship, perhaps, is likely to be *colder* than the external air, and when artificial means of ventilation cannot be employed, the wind should be taken advantage of as a motive agent.

The aspiratory power of the wind and the production of a head for ventilation, by the motion of air over the mouth of a tube, can be secured by covering air-shafts with cowls, which both aid up-currents and prevent down-draughts. This is practically the idea with which all the varieties of up-cast ventilators are constructed, however varied may be their external appearance. Cowls are uncertain in their action when affixed to buildings, owing to the variability of the wind-currents, due to the effects of the surfaces of the buildings themselves. Although many forms of cowl have been designed to render them serviceable, no matter from which direction the wind blows, there are practically only two types, namely, those with rotating cowls and those with fixed vanes. Of the former type, Banner's cowl may be regarded as a specimen; it sets itself by means of a wind vane so that the opening always faces away from the wind. The latter type is represented by Boyle's ventilator; in it the vanes are fixed, as shown in Fig. 16, so that from whatever direction the wind blows, the motion of the air is always tangential to the shaft opening. In all forms of cowl the air-current is both variable and small, and very liable to be overweighted by

the head from some other opening, so that what was primarily intended to be an up-cast often becomes a down-draught shaft.

Effects of Unequal Weights of Air.—Though constituting one of the causes of wind itself, it is necessary, in discussing ventilation, to look upon it as if it were an independent force. If the air in a room be heated by fire, or by the presence of men and animals, or be made moister, it endeavours to expand; and if there be any means for it to escape, a portion of it will do so, and that which remains will be lighter than an equal bulk of the colder air outside. The outer air will then rush into the room by every orifice, until the equality of weight outside and inside is re-established. But as the fresh air which comes in is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of openings, and hot air escaping by another.

We have now to inquire how the rate of this constant stream of air may be calculated. The mode most generally used is based on two well-known laws:—first, that the velocity in feet per second of falling bodies is equal to nearly eight times the square root of the height through which they have fallen; and second, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the partition. This is frequently called the rule of Montgolfier. The formula is $v = \sqrt{2g\text{H}}$; in which g is the acceleration of velocity in each second of time, viz., 32·18 feet, and H is the height of the descent. When simplified out, this formula becomes $v = 8\sqrt{\text{H}}$. The pressure of the air upon any surface may be represented by the weight of a volume of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is nearly 15 lb. on the square inch, and this would be the weight of a column of air of about 5 miles in height. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of five miles, viz., 1300 feet per second. But if, instead of rushing into a vacuum, it rush into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure outside and inside. In ordinary cases this difference of pressure cannot be obtained by direct observation, but must be inferred from the difference of temperature of the outer and inner air. We have already stated that air is dilated one part in 491 of its volume (0·00203) for every degree Fahrenheit, or one part in 273 (0·00366) for every degree Centigrade that its temperature is raised; consequently, the difference of pressure outside and inside will be as follows:—

The height from the aperture at which air enters to that from which it escapes, multiplied by the difference of temperature between outside and inside and by the co-efficient of expansion.

Example.—Say the height of a column of air in a chimney, between its throat and aperture of exit, be 20 feet, and that, owing to a fire in the grate below, its temperature be 15° F. above that of the outside air. Then the height to produce velocity of an inflowing and colder current will be $20 \times 15 \times 0{\cdot}00203 = 0{\cdot}609$ foot, and the velocity will be $8\sqrt{0{\cdot}609} = 8 \times 0{\cdot}78 = 6{\cdot}24$ feet. This, however, is the theoretical velocity. In practice, an allowance must be made for friction of $\frac{1}{4}$, $\frac{1}{3}$, or even $\frac{1}{2}$, according to circumstances. The deduction of $\frac{1}{4}$ would leave 4·680 linear feet per second as the actual velocity. If this be multiplied by the area of the opening, in feet or decimals of a foot, the amount of air is expressed in cubic feet per second, and multiplying further by 60 gives the amount per minute. If in this particular case the area of the chimney throat be a square foot, the amount of air escaping by the chimney under the above circumstances, and of course replaced by a similar volume of fresh and colder air, will be 281 cubic feet per minute.

This cause of movement is, of course, constantly acting when the temperature of the air changes. It will alone suffice to ventilate all rooms in which

the air is hotter than the external air, but will not answer when the air to be changed is equal in temperature to, or colder than, the external air.

As its action is equable, imperceptible, and continuous, it is the most useful agency in natural ventilation in cold climates, in inhabited and warm rooms; and in all habitations arrangements should be made to allow it to act. As the action increases with the difference of temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, or in hot climates, when the internal and external temperatures are identical.

Influence of Friction upon Air-currents.—The amount of loss produced by friction from various causes is often overlooked, and its neglect is apt to lead to failure and disappointment. The chief causes of loss are the following:—

(1) *Length of Tube or Shaft.*—Here with equal sectional areas the loss is directly as the length, so that if we take a shaft of 30 feet as a standard, a shaft of 40 feet long would have an increased friction of one-third.

(2) *Size of Opening.*—For circular sections the friction is inversely as the diameter. Thus for two openings, respectively 1 and 2 feet in diameter, the friction at the smaller opening will be twice that of the larger. In this way dividing up an opening into a number of smaller apertures, the aggregate of which is equal to the original opening, produces a loss by friction in the direct ratio of the diameters. An opening of 1 square foot divided into four openings of $\frac{1}{4}$ of a square foot loses in the ratio of 1 : $\frac{1}{2}$, being respectively the diameters of the openings. When the shapes of the openings are not circular, the loss by friction may be stated as inversely that of the square roots of the areas. Thus if 1 square foot be divided into nine openings, each equal to $\frac{1}{9}$th of a square foot, the loss will be in the ratio of $\frac{1}{3}$: 1, viz., inversely as the square roots of the respective areas.

(3) *Shape of Opening.*—A circular opening may be taken as the standard, that being the figure which includes the greatest area within the smallest periphery. The loss sustained from any other shape being used will be proportionate to its difference from a circle enclosing a similar area. Thus, if we have two openings, each of 1 square foot area, the one being a circle and the other a square, the length of periphery of the latter will be 4 feet, of the former $3\frac{1}{2}$; therefore the velocity of the current through the square opening will be $\frac{3\frac{1}{2}}{4}$ or $\frac{7}{8}$ of that through the circular opening.

(4) *Angles in the Tube or Shaft.*—This is a most serious cause of loss. The exact formula has not been distinctly determined, but it may be accepted, as in accordance with experiment, that every right angle diminishes the current by $\frac{1}{2}$, so that two right angles in a tube would reduce it to $\frac{1}{4}$, and so on. Yet it is no uncommon thing to find tubes and shafts bent recklessly at numerous angles to fit a cornice or architrave, to save expense and appearance.

(5) The presence of dust, soot, or dirt of any kind seriously interferes with the current, but this may of course be obviated by a moderate amount of care and attention.

It is obvious that attention to the above points is necessary to obtain success in any scheme of ventilation.

It is advisable generally to widen slightly the orifices of shafts, especially if they are of small diameter, as the current tends to be contracted and obstructed at that point. At every change of direction the same effect takes place. Hence the desirability of rounding off angles as much as possible, where they cannot be altogether avoided.

It is generally best to have the sections of shafts circular or elliptical instead of rectangular, for not only is there less loss by friction originally, but there is less chance of lodgment of dust, &c., and they can be more easily and thoroughly cleaned.

Comparing two sets of schools in Dundee, Carnelley, Haldane, and Anderson have shown that mechanical ventilation has the advantage. In naturally ventilated schools, the average amount of CO_2 was 1·86 per 1000 vols., the organic matter 16·2 (vols. oxygen required per million vols. of air), and the micro-organisms 152 per litre ; while in mechanically ventilated schools, the CO_2 was 1·23, the organic matter 10·1, and the micro-organisms 16·6 : and notwithstanding this greater purity of the air, the temperature was considerably higher in the latter. The incoming air is warmed by being driven by means of fans over hot pipes, and then delivered into the rooms, about 5 feet from the floor, through shallow broad openings ; the outgoing air is drawn up from apertures about 2 feet from the floor into a chamber in the roof and thence out through valved louvres. The mean delivery of air (calculated from the CO_2) in the mechanically ventilated rooms was 670 cubic feet per head per hour—in those naturally ventilated, only 400 ; the range in the former being from 375 to 1680, and in the latter from 175 to 1370. In neither case, however, was the ventilation very good.

METHODS OF HEATING AND COOLING.

Just as, in discussing the problems of ventilation, we were largely concerned in considering the various natural and mechanical processes involved in air movement, so now, in dealing with the problems relating to the heating of buildings, we have to discuss the laws governing the production and distribution of heat. In actual practice the problems of ventilation are very closely associated with the problems of heating, because heat is one of the most important agents in ventilation, and the distribution of heat is commonly dependent upon the distribution of heated air or water.

Production and Measurement of Heat.—The production of heat for the purposes of heating and ventilating buildings is commonly effected by the combustion of fuel. The chief constituents of fuels are carbon and hydrogen, with various chemical combinations of these two elements ; while the principal products of their combustion are carbon dioxide and water.

For measuring and comparing quantities of heat, a unit of measure is required, and that which is most commonly used in this country is the amount of heat required to raise a pound of water 1° F., say from 32° F. to 33° F. This is sometimes spoken of as the British thermal unit. In the metrical system, the unit of heat is the calorie, or the amount of heat required to raise a kilogramme of water from 0° C. to 1° C. It is sometimes convenient, in ventilation and heating problems, to express the amount of heat in terms of force. When so expressed the British thermal unit is equivalent to 772 foot-pounds of force and the calorie is equal to 423·985 kilogramme-metres, each kilogramme-metre being equal to 7·2 foot-pounds, or one calorie is equal to 3·968 lb. Fahrenheit units.

The quantity of heat produced by the combustion of a fuel is approximately the sum of the quantities of heat which the hydrogen and carbon contained in it would produce separately by their combustion. When hydrogen and oxygen exist in a compound in the proper proportion to form water, these constituents have no effect on the total heat of combus-

tion, and it is only the surplus of hydrogen above that which is required by the oxygen that is to be taken into account. From these principles and by exact observation, it is calculated that a pound of coal will yield 15,000 British thermal units, a pound of coke 13,000 units, a pound of dry wood 7000 units, and a pound of petroleum 21,000 units.

Specific Heat.—As we have chiefly to do with questions involving the amount of heat in different quantities of air, water and watery vapour, the exact amounts of heat which can be stored in equal weights of these different substances, by raising their temperatures through the same range, become of material importance. The heat capable of being stored or retained in this way is called the *specific heat*, and is usually described as being so many units required to raise the temperature of 1 lb. of the substance through 1° F. From the following table of specific heats, it will be easy to compare the efficiency of different substances for the storage of heat.

Water requires	1·0000	British	thermal unit	to raise the temperature	of 1 lb.	through 1° F.
Ice „	0·5040	„	„	„	„	„
Steam „	0·4800	„	„	„	„	„
Copper „	0·0951	„	„	„	„	„
Iron „	0·1140	„	„	„	„	„
Brass „	0·0939	„	„	„	„	„
Firebrick, Wood require	0·2000	„	„	„	„	„
Air (expanding) „	0·2380	„	„	„	„	„
„ (volume constant)	0·1690	„	„	„	„	„

From this table it is evident that, weight for weight, water will absorb more heat for the same rise of temperature than any other substance, hence the comparative economy secured by using water as a carrier of heat, instead of air. In the case of the former it is unity, while for the latter it varies from 0·169 to 0·238, according as to whether the volume of the air mass is constant or expanding.

Distribution of Heat.—In order to understand thoroughly the principles of applying heat, it is necessary to remember that the heat evolved from fuel is disseminated to surrounding bodies by conduction or immediate contact, by radiation, and by convection. Heat is *conducted* through all solids, but to a very limited degree only by liquids and gases. Bodies which are good conductors give heat off rapidly to the surrounding air or to anything in contact with them; in like manner, if colder, they withdraw heat from other bodies. The heat-conducting power of a number of common substances may be expressed by the following list, in order of merit from highest to lowest:—copper, iron, lead, slate, glass, water, brick, asphalt, wood, wool, air, and asbestos.

Radiation is not only the most common, but probably the most wasteful of the ways by which heat is distributed. Radiated heat is propagated in straight lines in all directions with equal intensity, the effect lessening according to the square of the distance; thus, if the heat at 1 foot distance from a fire be 1, then at 10 feet it will be 100 times less. If radiant heat fall on a solid body, it is reflected in the same way as light, but some of the heat is absorbed, the amount reflected and absorbed being in inverse proportion to one another, and largely dependent upon the surface, colour, and nature of the body, as well as upon the difference of temperature between the receiving and radiating bodies. Speaking generally, we may say that good radiators are good absorbers; good reflectors are bad radiators; transparent bodies are bad radiators.

Different transparent substances often exhibit remarkable variability as to radiation. Dry air is very transparent, but, if moist, is often more or less opaque, and becomes heated itself when heat is radiated through it. Similarly, a glass plate, 0·37 inch thick, will absorb half the energy of

radiation which falls upon it, but transmitting the other half; hence thick glass is often effective in screening off heat from the sun or fire, while at the same time transmitting the light.

The *convection* of heat is the mode in which heat is propagated in liquids and gases, and is dependent upon the characteristic of those bodies which allows the portions of them which have been heated to expand and rise, their place being taken at once by colder parts. A sort of circulation of the water or air is set up, and the whole mass soon warmed. Every person in a room causes convection currents by the heat conducted to the air in contact with his skin or clothes; while the air of a room, with a fire in it on a cold day, is in a highly complex state of movement, from a similar cause. The convection currents produced by fires and by the human body in an atmosphere colder than itself not only carry off some heat, but incidentally provide the body with a supply of fresh air. When the temperature of the surrounding air is nearly that of the body, this natural replacement of air does not take place, necessitating an artificial movement of the air either by means of fans or by punkahs as in the East.

Disregarding any particular variations in the source of heat, that is, whether from coal, coke, wood, gas, or oil, we can say that the principal methods of warming and heating houses or rooms may be classed as either open fires, closed fires or stoves, and pipes containing either heated air, hot water, or steam.

Open Fireplaces.—Long-established custom and prejudice have caused open fires to be the means of heating nine-tenths of the houses in England, notwithstanding the fact that they are really the most costly and imperfect means of heating, as evidenced by the fact that they only render available 13 per cent. of the total heat capable of being yielded by coal or coke, and only 6 per cent. of that by wood, the rest being lost in the air, or escaping as unconsumed carbon up the chimney. The actual heating effect of open grates is most unequal in different parts of a room, but on account of the cheerful light which they emit, and the ventilation which they ensure, open fires will always be preferred as the pleasantest and healthiest mode of heating. Following Teale, the chief practical points to be aimed at in making open fireplaces may be summarised as follows:—(1) Use as little iron, but as much firebrick, as possible; (2) the back and sides should be made of firebrick; (3) the back of the fireplace should lean or hang over the fire, while the throat of the chimney should be contracted; (4) the bottom of the fire should be deep, from before back; (5) all slits in the bottom of the fire should be as narrow as possible; (6) the bars in front should be narrow; (7) the space beneath the fire should be closed in front by a close-fitting iron shield or "economiser." The object of this latter point is to secure as complete combustion as possible of the fuel at the bottom of the fire by the exclusion of cold air. In the use of an ordinary open fireplace, about one-eighth of the heat given off by the fuel consumed is utilised on the air of the room. All open grates should be made so as to have the fuel slowly and completely consumed, while the draught up the chimney should not be in excess of ventilation requirements.

The average open fireplace consumes from 6 to 8 lb. of coal in an hour; this means a theoretical need of from 1600 to 2400 cubic feet of air hourly, but in actual practice anything from 9000 to 20,000 cubic feet of air pass up the chimney. If the incoming air were warm this liberal ventilation would be excellent; but, unfortunately, it rarely is so, but is in the main cold, finding entrance through the floor, or by chinks round the windows or beneath the door.

If the whole of the heat generated in the combustion of coal were utilised, 1 lb. would suffice to heat a room 20 feet square by 12 feet high 10° F. above the temperature of the outer air, that is, making no allowance for loss by ventilation and conduction. To save some of the large margin of 86 per cent. of practically wasted fuel has been the object of many "improved fireplaces."

One of the first improvements in fireplaces was the securing of increased radiation from the burning fuel. This is best attained by either regulating

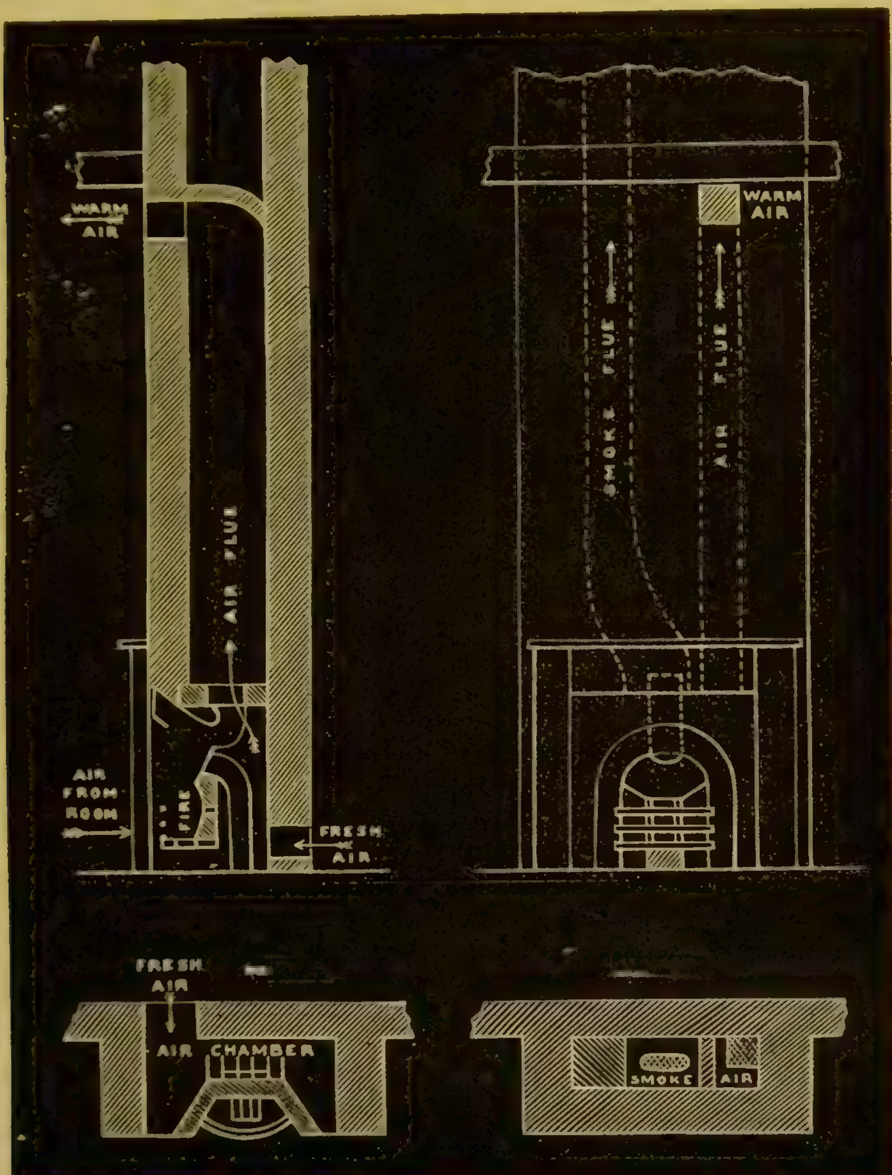


FIG. 17.—GALTON'S VENTILATING GRATE.

the shape of the stove so that its coverings are inclined at an angle of 135° to the back of the grate, or by making the fireplace as much as possible of material which, while having a high radiation power, is but a poor conductor of heat. Fireplaces on this account should be made as far as possible of firebrick, and the amount of metal about them reduced to a minimum. Several grates improved in this direction are now in the market, more particularly some constructed almost entirely of fireclay or pottery.

Fireplaces have further been improved by surrounding the stove by an air space with two openings which communicate, one with the external air,

and the other with the room. The air entering this chamber behind the grate becomes warmed by passing over the heated back portion of the fire-place, and then ascends by a separate shaft or by an iron pipe placed in the chimney to enter the room near the ceiling. The ventilating fireplace of Sir D. Galton (Fig. 17), largely used in military barracks, is a very good form of this class of firegrate. Boyd's Hygiastic grate is another construction on the same principle, but delivers the heated air through an opening just above the fire under the mantelshelf. Both these grates reduce the wasted heat by about one-fourth. It is, however, important that the air which enters by these ventilating fireplaces should not pass over any iron surface which is heated to a red heat, as, owing to the direct action of the oxygen of the air upon the carbon of the cast iron, and the frequent decomposition of the atmospheric carbon dioxide by the red-hot metal, free carbon monoxide may be generated. To these reasons may be added the fact that, if any carbonic oxide is formed in the fire, some of it will pass out through the red-hot metal to the external air. "Slow combustion grates," having solid floors, are now much used. The fuel, which is piled up against the back, burns away mostly at the upper part, where the current of air strikes the top of the fuel on its way to the chimney. The fuel is brought well forward, so that the heat may be radiated freely, and the flanks of the fireplace are splayed for the same reason. The fire is lighted at the top, and gradually burns downwards.

In some other grates, economy of loss of heat is gained by limiting the amount of air carried up the chimney without having taken part in the combustion. This loss of heat can usually be restricted by narrowing the chimney and its orifices, but care needs to be taken that the proper proportions of the chimney and its openings are maintained, so that the efficiency of the fireplace, as a ventilating and warming apparatus combined, is not interfered with. To secure this, Morin * recommends that the temperature of the air in the chimney should be at least 45° F. or 25° C. above that of the outer air, and that the smoke should not issue from a chimney at a greater velocity than 10 feet per second, and that the top orifice of the chimney should be one-half of that of the chimney itself.

Of late years, much attention has been devoted to the improvement of the open domestic grate, notably towards securing a maximum amount of heating effect with a minimum consumption of fuel and a minimum production of smoke. Good examples of these efficient grates are the "Devon," the "Hygiastic," and the "Draw-well." The *Devon* grate is constructed entirely of fireclay ware and made to radiate the heat towards the centre of the room. The lower portion of the fireplace has a solid bottom, directly upon which the fire burns, there being no grid or air chamber beneath. It is claimed that the most perfect combustion is obtained by so placing the fire immediately on a solid block of fireclay, and that with such an arrangement the question of ashes presents no difficulty. The *Hygiastic* grates are supplied with fresh air from outside with the object of letting it circulate round the back of the grate and then to enter the room through a grating over the fire in a continuous stream. The front is of cast iron, fitted with or without a canopy. The backs are of fireclay and sloped to facilitate radiation, and have unbreakable joints which will not crack by unequal expansion. There are regulating valves for smoke and air, and a box ash-pan under the fire. The bars slope inward with the intention of deflecting air into the fuel and preventing cinders or coal from dropping out. The

* Morin: *Etudes sur la Ventilation*, Paris, 1863; also *Manuel pratique du Chauffage et de la Ventilation*, Paris, 1874.

Draw-well grate is fitted with an adjustable canopy, and has a semicircular and solid brick back sloping inwards ; the bottom forms a dish or basin with a bar-grate which lifts out. There is a ventilating fret with pan attached. When the fire is out, the bottom grate can be lifted up and the dust and ashes removed in the pan without causing them to fly about the room.

Taking these grates to represent the best types of open fireplace, we find their efficiency is low, in that the percentage of total heat, generated from the fuel burnt, given to the air of the room is under 7. The percentage of total heat lost in the flue is about 14, and the percentage of total heat given to the walls of the room is, roughly, 79. This heat given to the walls is not lost heat, as it is radiated out again into the room and constitutes an important factor in respect of comfort to the occupants, as a room with warm walls is a warm room, just as one with cold walls is a cold room. As ventilating agents, the best types of open fireplace cause some 2600 cubic feet of air to pass up the flue per pound of coal consumed, or the passage of about 18,000 cubic feet up the chimney per hour. If we add the chimney losses to the heat given to the air of the room, the combined heat efficiency of open fireplaces of a good type may be said to be from 21 to 23 per cent., which, compared with the 22 per cent. usually obtained from radiators, is not unfavourable to the open domestic fireplace, more particularly if we take into account that the latter is a ventilating agent, while the other is not. For fuller information regarding these and other developments towards efficiency the Reports of the Coal Smoke Abatement Society should be consulted.* In the matter of smoke-production the results afforded by certain grates burning anthracite coal are remarkable in comparison with those consuming bituminous coal ; if further effort should succeed in securing a corresponding increased heat production with economy in fuel, a valuable achievement will have been accomplished.

Closed Fires or Stoves.—The simplest definition of a stove is that of a chamber constructed to disseminate heat by the direct contact of air with the heated surface, which is obtained by burning fuel on a grate, closely surrounded on all sides, except below the bars, by a good conducting or absorbing material. If the fire is not required materially to assist in ventilation as well as in heating, the enclosing of the fire in a chamber affords a considerable economy in the consumption of fuel, as the air supplied is entirely limited to that taking part in the combustion, and only the products of that combustion escaping by the chimney or smoke-flue. The materials used for the construction of stoves are cast iron, sheet iron, bricks or tiles, and much of the success of stoves depends upon the facility with which the materials of which they are constructed communicate the heat they receive.

When the fuel is rapidly burnt in a stove, so as to evolve at once the entire amount of heat it is capable of affording, the temperature produced is often greater than is required. Iron, therefore, which conducts and radiates heat almost as rapidly as it is received, is not an appropriate material for communicating a uniform temperature, say of about 68° F. Clay, in the form of bricks or tiles, is decidedly preferable, as no matter with what degree of rapidity its temperature is raised, it evolves its heat slowly and gradually.

Iron stoves are often objectionable, because they occasion an unpleasant smell, and produce headaches. The smell is commonly caused when, by want of attention, some part of the stove is allowed to become red-hot, and the dust particles in the air, coming in contact with it, are charred ; often a slight smell comes from the iron itself. Another objection exists in the

* *See* the *Lancet*, 1906, vol. i. p. 1413 ; also 1906, vol. ii. pp. 182 and 1361.

fact that iron, when red hot, permits the passage of carbon monoxide and other gases through it. If water is not placed on a stove, the air becomes heated without acquiring an amount of moisture commensurate with its increased temperature, and is proportionately unpleasant.

In stoves of the simplest construction, the fire is surrounded directly by the surface to be heated, which, being placed unprotected in the room, radiates heat and warms the air by direct current, the smoke passing away into the chimney.

In Napier's stove (Fig. 18) every effort is made to economise fuel, and the heated gases caused to descend before entering the chimney. This principle of conducting the gases downwards before they are allowed to escape is scientifically correct, because the heavier or cooler gases escape first, the hotter gases being kept longer in contact with the radiating surfaces of the stove; better diffusion of the hot gases is also obtained in this way.

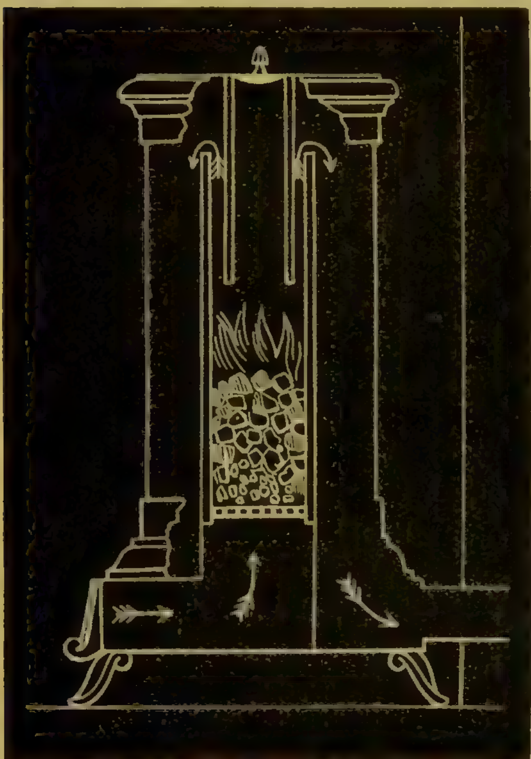


FIG. 18.—NAPIER'S STOVE.

The Meidingen stove is a slow-combustion stove much used in Germany; it consists of an inner cylinder with fluted rings enclosed in a double casing, through which the outer air can be passed and warmed before entering the room. A door fixed in the grate regulates the draught and the rapidity of combustion.

In some stoves, the heating surface is surrounded by an outer casing open at the top and bottom, through which the air of the chamber or air from the outside is caused to circulate and become warmed in its ascent. These arrangements are often called cockle stoves; large stoves on this plan used on the Continent are known as *calorifères*.

Gas Stoves.—The use of appliances employing illuminating gas as fuel in heating and cooking has largely increased of late years, several exhibitions of such appliances having greatly stimulated the introduction of improved forms. Gas stoves without chimneys, that is, those from which the products of combustion are allowed to escape into the air of the room which is being heated, are obviously fundamentally wrong, and are only used where health is sacrificed to economy of gas. Under certain circumstances, gas is a more economical fuel than coal; where heat is required quickly and only for a short time, the waste which necessarily accompanies the lighting of a coal fire is far more than equivalent to the higher cost of the gas.

Speaking generally, there may be said to be three common forms of gas stove in general use:—these are (1) coke and asbestos or hollow ball refractory fuel stoves; (2) reflector stoves; (3) condensing stoves.

Stoves fitted with coke, asbestos fibre, common peroxide of manganese, pumice-stone, and firebrick, and lighted by Bunsen burners, are relatively popular, owing to the fact that the fuel is rendered incandescent, with a close resemblance to the glow of an ordinary coal fire. These stoves yield

radiant heat only as a rule, though a few are made with attached hot chambers to give off heated currents of air. They are, in the main, good stoves, but somewhat extravagant as gas consumers, always needing a flue to carry off the products of combustion, which as well takes much of the heat produced as so much waste. Gas fires of this kind for an ordinary room consume from 25 to 60 cubic feet of gas per hour.

Reflector stoves have usually a naked gas flame, backed by a glass or metal reflector. They are bright and cheerful-looking, but give out little heat and, unless provided with a flue, add very considerably to the vitiation of the air.

Condensing stoves are those so constructed that the water vapour, which is one of the products of gas combustion, is condensed by passing through upright tubes, and then caught in a tray beneath. This condensed vapour naturally carries down with it some if not all the sulphur products, but fails to remove any of the carbon dioxide which, notwithstanding all statements to the contrary, really escapes into the room. For this reason, these stoves always require a flue; unfortunately, their heating powers are small.

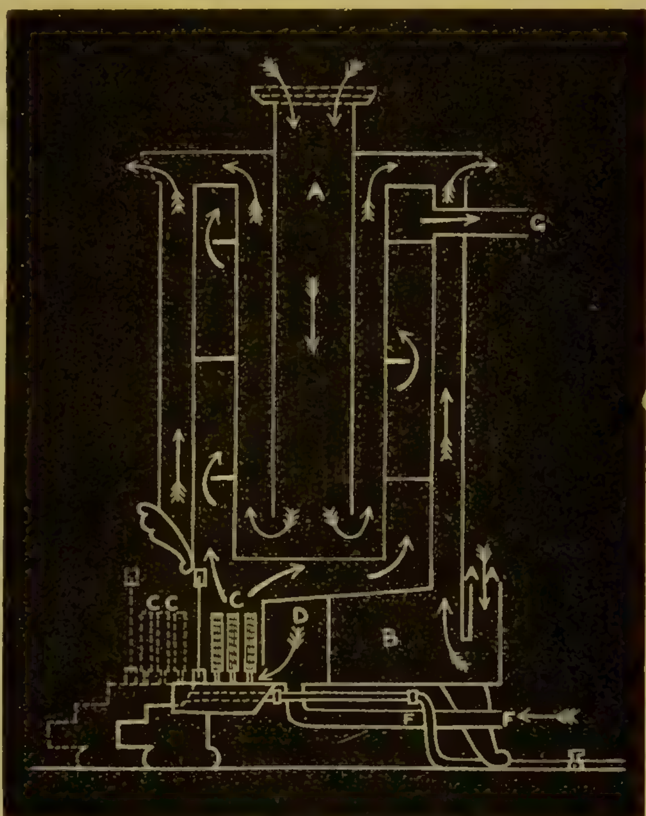


Fig. 19.—Adams' Stove.

The essential defects of all these forms of gas stove are a disproportionately low amount of heat gained as compared with the high expenditure of gas, due mainly to a failure to rob the products of combustion of their heat before they escape out of the stove in as large a degree as is consistent with ensuring their escape from it. It is at once obvious that this can be most effectively secured by bringing the heated combustion products into contact with a large metallic area, so arranged that the heat which it absorbs shall be given off either by direct radiation, or by the conducting influence of air-currents flowing over it. Of stoves which provide luminous flames, or a source of radiant heat as well as a supply of fresh heated air, those of Adams and Fletcher may be taken as examples; while of the numerous stoves which merely supply heated air, those of George and Bond will serve as specimens.

In Adams' stove (Fig. 19) a mixture of gas and air is burned in a series of fireclay burners. These are arranged upon a tray, which is drawn forward for lighting; in a short time the burners become red hot, and a small supply of gas then suffices. The heated products of combustion are passed over a large surface formed by sheet-iron partitions, the other side of which is traversed by the air which is being heated; a certain amount of radiation also takes place from the red-hot brick burners. The waste hot

gases escape by a chimney at about 240° F., while a supply of fresh air is drawn in and rapidly heated to 180° F. at a rate of about 200 cubic feet per cubic foot of gas burned per hour.

In Fletcher's gas stove use is made of simple illuminating flames from ordinary burners for the supply of radiant heat; the hot combustion products ascend in contact with vertical tubes, which are thus heated, and induce a current of air through them, the air being delivered heated at the top (Fig. 20).

In George's Calorigen stove the body is made of rolled iron, and contains a coil of wrought-iron tubing open at the top. This at its lower end is carried through the outer wall, either above or below the floor, to a point from which an appropriate supply of fresh air can be obtained. The cylindrical metal body of the stove has connected with it two pipes, one, an

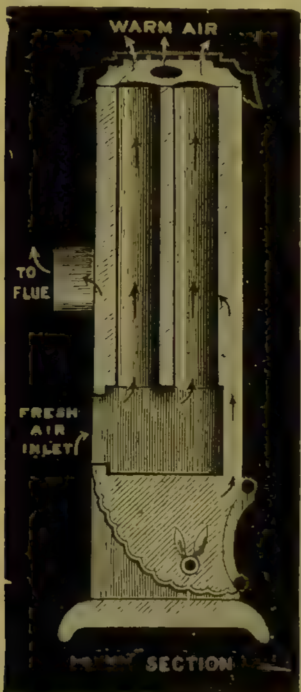


Fig. 20.
Fletcher's Stove.

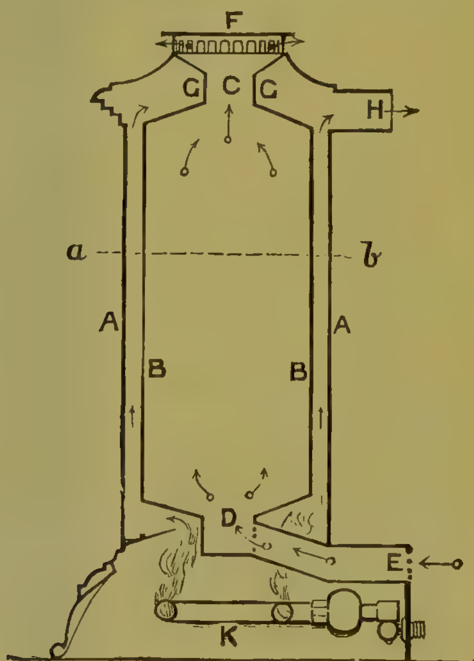


Fig. 21.
Bond's Stove.

upper one, for carrying away the products of combustion into the outer air, while the lower one brings in fresh air to support combustion. The action of the stove is simple; the heated combustion products not only warm the outer metal case, and through it the air in contact with it, but also heat the current of air constantly passing up through the coiled tube into the room.

Bond's Euthermic stove (Fig. 21) consists of a corrugated metal cylinder which, as in George's Calorigen, constitutes the stove body; above this, it discharges into a flue for the escape of the combustion products, while below, it is open for the location of a gas jet and a supply of air. Inside this metal cylinder is a metal drum, having an inlet tube, E, below, for bringing fresh air, and open at its upper end, to allow of air which is heated in its passage through the stove to escape into the room. The corrugation of the cylinder secures not only an increased superficial surface for the heated products of combustion to yield their heat into the room direct from the outer surface of the corrugation, but also from the inner surface of the contained drum to the air within it.

A recent inquiry, by the Coal Smoke Abatement Society, relating to the thermal efficiency and hygienic considerations of gas stoves, has supplied us

with much valuable information.* Taking eight of the best stoves tested we find that the average hourly consumption of gas varied from 23 to 66 cubic feet. The average volume of air passed through the room, reduced to 60° F., was 71 cubic feet per cubic foot of gas burnt, and one hour elapsed from lighting of these stoves until a fairly steady temperature was reached in the room. None of the stoves tested gave any smell or carbon monoxide to the air of the rooms in which they were placed; while the average increase of carbon dioxide in the air of the room above that of the outer air was 1·5 parts per 10,000. The average consumption of gas per hour for each degree of rise in temperature (F.) in the room as compared with the air in the corridor outside was 3 cubic feet, and the cost per hour per degree rise of room temperature above that of outside corridor, taking the gas to cost three shillings per 1000 cubic feet, was just one-tenth of a penny. It is interesting to note that the best coal-burning open grates, tested in the same rooms, worked out at a cost of 0·026 pence per degree (F.) of rise in temperature. Among the stoves tested, the following appear to have presented the most favourable features, namely, the Cannon Company's "Iris" and "Large Victory," Main's "Chelsea," Richmond's "Ilford" and "Royal Sovereign," Fletcher's "India," and Davis' "Beaufort" and "Albany."

One of the most important points which came out of these tests was the very great ventilating effect produced by providing an independent entrance for air to the flue besides that through the stove. It is recommended that all gas stoves should have an opening provided, either in the stove casting itself or in the plate which usually closes the grate recess. This opening should be capable of regulation in size, and the area of such opening, or the combined areas of all, should there be more than one, should not be less than about 20 square inches when fully open. It is believed that this arrangement will help to remove the popular impression that gas fires vitiate the air of the rooms in which they are burning.

There is a tendency in many gas stoves, when first lighted, to produce a smell in the room; this is due to the slow establishment of a proper draught, which could be avoided by attention to certain principles, as follows:—The flue should, in the first place, be of sufficient size, preferably not less than 4 inches in diameter, as the losses through the flue are not so great as many think. When the flue is connected to the stove, above the fire, it should not be horizontal, but have a gradual rise to the main flue so as to encourage the initiation of an upward draught; this would do away with the "elbow"; an objectionable feature in nearly all gas stoves. Such sudden bends or changes in direction should be avoided as they impede the draught, and although of little importance when the flue has been heated and the draught properly established, they are of great importance when the flue is cold and the draught feeble. In stoves with heating chambers a direct connection might be made to the main flue as indicated above, and when the draught has been established this connection might be closed by a damper, and the hot gases directed around or through the heating chamber. The opening of the stove flue should be at the highest point, otherwise a pocket is formed there in which the flue gases collect, and, should there be any leakage due to faulty joints, find their way into the room. The bottom of the flue opening should be well above the lower edge of the stove canopy. If this is not so, there is danger of the flue gases filling the pocket under the canopy and flowing out into the room.

For supplying the gas which is now usually supplied to gas stoves, use is made of so-called atmospheric burners constructed on the same principle as

* *Lancet*, 1906, vol. ii. p. 1361.

Bunsen burners. From the supply-pipe the gas passes by a nozzle into a small chamber provided with perforations behind the nozzle, through which air passes. The air and gas mix, and, escaping by the jets, on ignition burn with a non-luminous, faintly blue, smokeless, but extremely hot flame. If the supply of gas be too small, it burns at the nozzle, producing an easily recognised odour of half-burnt gas. This "burning down" always occurs if the gas is turned too low, or when the gas is exposed to a sudden draught. It constitutes a serious drawback to the use of gas fires. Many atmospheric burners are now made with devices for preventing the lighting back, one of the best being to cover the openings at which the gas burns with fine wire gauze.

Oil Stoves.—Under some circumstances the use of oil stoves affords a convenient means of heating apartments. This is a matter of great practical importance often in country places, and where no chimneys are available to carry off the products of combustion. The problem how to make a stove that shall not require a flue is one that has occupied the minds of many inventors, and although it is easy to say that so long as carbon dioxide is one of the products of combustion the thing is impossible, there is a good deal of experience to show that a considerable degree of heat may be safely obtained from the combustion of hydrocarbons, without any other flue or outlet than is required for the removal of the products of respiration of those who dwell in the room. We do not think that the experience has yet been accumulated which would enable us to speak positively of the innocuousness of a considerable admixture of carbonic acid with the air we breathe, but the knowledge that in hundreds of cases oil stoves are used for heating living-rooms and even bedrooms without apparent injury to the occupants, makes one feel fairly confident that the products of the complete combustion of hydrocarbons are not injurious when mixed with such an amount of air as is sufficient to dilute to a proper degree the respiratory products.

Experiments show that, provided the combustion of the oil is complete, and that the ventilation is sufficient for the ordinary effects of respiration, the use of oil stoves for heating purposes may be advantageously employed in both ordinary day- and sleeping-rooms. The efficiency of oil stoves is increased by placing over them a diffuser or radiator, so as to prevent the heated products ascending direct to the ceiling ; care needs also to be taken that only the better kinds of mineral oil are used ; if inferior qualities of oil are burnt, perfect combustion is more difficult to obtain.

Heating by Means of Hot Air.—When want of space or other considerations render it desirable to remove stoves or fires away from the rooms to be heated, the necessary quantity of air can be warmed in another part of the building, and conducted by air flues into the different rooms or passages. This arrangement is eminently suitable for large public buildings. When the supply of heated air is abundant, and is transmitted to the apartments with some force by means of fans, no extra outlet for the vitiated air is necessary, sufficient ventilation being afforded, in small rooms and not overcrowded with inmates, by the unavoidable cracks and crevices around doors and windows. If, however, the rooms are at all crowded, special means of ventilation must be provided. With a view to economise the heat of the air, which has already circulated once through the apartments, two methods have been proposed :—one consists in reconducting the air to the heating surface of the stove, and again transmitting it to the spaces to be warmed ; the other conducts the used air to the ash-pit of the stove to supply oxygen for combustion, when the higher temperature, as compared with the

external atmosphere, which it still retains, will more than compensate for the lesser proportion of oxygen which it affords.

Supposing that proper ventilation can be kept up in the rooms by means of doors and windows, the first method is obviously advantageous, as the warm air streaming in will force out that already in the room, and thus produce a condition of affairs in which the natural tendency of the outer air to force its way through crevices with all its attendant disadvantages will cease. The methods of heating by hot air are not desirable for buildings in which the number of rooms heated varies, because the proper relation between the dimensions of the heat generating stoves and the supply of hot air cannot be easily apportioned to meet a fluctuating demand. On the other hand, this manner of heating is economical, as only one stove is required and its fuel more completely consumed than if the same quantity were distributed in separate stoves, while there is the further advantage of a uniform and equable heat proceeding from the floor level.

The actual generating hot-air stoves are constructed according to either of two systems. In one, the smoke and hot gases from a fire are caused to circulate in an extensive series of stoneware or metallic flues, and the air to be warmed, supplied from the outside of the building, is conducted around these flues, where it absorbs heat. In the other, the air to be heated is conducted through metallic or stoneware pipes, round which the flame and smoke of a fire are allowed to play. In both systems, about 10 square feet of heating surface per pound of coal consumed is found practically to work well. The forms of apparatus constructed by different inventors for heating air are numerous, but they all conform in principle to one or other of the foregoing systems.

Heating by Water and Steam.—Both water and steam are often used as means of carrying heat, in consequence of the high specific heat of the former, and the large quantity of latent heat in the latter. The quantities of heat contained in equal weights of water and air at the same temperature are in the ratio of 421 to 100; or the heat which is set free when water cools down 100 degrees is sufficient to raise the temperature of 4·21 times as much air to the same amount. Therefore, the heat destined for a given quantity of air can be retained in a much less quantity of water. Further, a greater effect is produced when water, in the form of steam, is made the carrier of heat, because 1 lb. of water vapour at 100° C. (212° F.) will, in condensing to form boiling water, give off sufficient heat to raise the temperature of 5·36 lb. of water, or 22·5 lb. of air to 100° C.

Heating by hot-water pipes is either conducted on the so-called low-pressure system, or on Perkins' high-pressure principle. In a low-pressure water system, the pipes are about 4 inches in diameter, and arranged in a double row to allow of the water circulating. The boiler in connection with it is commonly placed in the basement of the building, and from its upper part runs a main pipe, ending in branches, which extend to the furthest end of the building; these then return underneath the others, unite into another single pipe, and then re-enter the boiler at its bottom. The circulation of the water is dependent upon the water, after being heated, being lighter than when cold, and as such tending to rise to a higher level; this, having given up its heat to the various rooms, returns cooled by the lower pipe. The heat of the pipes is controlled by a valve which can be opened and closed at will. A feed-pipe from a supply-cistern enters the return pipe near the boiler, while an escape of air is provided at the highest point of the system.

The circulation being open to the air at one point, the highest temperature possible at or near the top, where this opening is, does not exceed

100° C. or 212° F.; at the deeper portions it may be higher, but the average temperature in a low-pressure circulation rarely exceeds 212° F. The calculation of the flow of water in a circulation is very similar to that of air; the head being due to difference of densities between hot and cold water. However small the head may be, there will be a flow of some sort, provided there is a continuous channel filled with water from the boiler and back again. The precise velocity of flow of water in the circulation depends not only on the head but upon the resistance of the whole channel. Its computation is subject to the same laws as those governing resistance in air-channels, but as the calculation for a hot-water system would be very intricate, most hot-water engineers work empirically from known successful arrangements to any new one required.

In Perkins' high-pressure system the water is completely enclosed in wrought-iron pipes, sufficiently strong to withstand the pressure corresponding to very high temperatures. The pipes are so arranged as to form a complete circuit, part of it being coiled within and exposed to the heat of a fire. At the top of the circuit there is a series of larger pipes called expansion tubes; these contain half air and half water, and therefore allow for the expansion of the latter. When the pipes have been filled with water, they are closed with screw plugs, making the whole circuit practically a closed vessel full of water except at the top, where there is a little air. The temperature is regulated by fixing the proportion of pipe within the fire to that outside as 1 is to 10. Once started, the circulation of water within these high-pressure pipes is very rapid, while the temperature usually reaches 300° F. This system has faults due to the irregularity of temperature at different parts of the same coil, and the rapidity with which the heat diminishes on lowering the fire. High-pressure water pipes are also very liable to overheat the air, a fact which renders them objectionable for heating houses; on the other hand, they are very useful for heating disinfecting chambers and drying closets, where a small space is required to be quickly raised to a high temperature. Wherever there is a high-pressure water circulation, it must not be forgotten that, although the whole is closed up, the water in it wastes to a small extent, necessitating the periodical opening of the plugs and the addition of a little fresh water.

It has already been explained that steam heats much more effectively than water, and that 1 lb. of steam at 100° C. will, in condensing to form boiling water, yield sufficient heat to raise 22·5 lb. of air to 100° C. (212° F.). Methods of heating by steam are based upon this fact, that if steam be conducted to suitable condensing pipes or tubes, they then will impart the generated heat to the surrounding air. The pipes destined to carry the steam to the place of condensation are chosen of narrow bore (about 1·5 inch), and, to avoid all condensation in transit, are surrounded with a thick covering of felt; the condensing pipes are of copper or cast iron, and at least four times as wide, and must be so arranged that the air can escape when the steam is first admitted. Whatever form is given to the apparatus, ample means must be afforded for the removal of the condensed water, and a special set of pipes, conducting it back to the boiler, is generally employed for this purpose.

A question of very practical importance is how much hot-water piping of given external diameter is necessary for the heating of a given room or series of rooms. The answer to this question depends upon a large number of conditions, more especially the loss of heat by conduction through the walls and windows, as well as that carried away by the air in the process of ventilation. Much of our information on this matter is due to Hood, who says:—

"The quantity of air to be warmed per minute in habitable rooms and in public buildings must be from 3·5 to 5 cubic feet for each person the room contains, and 1·25 cubic foot for each square foot of glass." According to the same authority, an iron pipe, 4 inches in external diameter, loses 0·851 of a degree of heat (F.) per minute (or 1° F. in seventy seconds) when the excess of its temperature is 125° F. above that of the surrounding air. Hood estimates also that 1 foot of a 4-inch pipe will heat 222 cubic feet of air 1° F. per minute when the difference of temperature of pipe and temperature of air is 125° F.

Putting it in another way, we can say that one British thermal unit will heat 50 cubic feet of air 1° F., and that the amount of heat given off from iron pipes containing steam or hot water is 1·75 thermal unit per hour per square foot of radiating surface for each Fahrenheit degree of difference between the temperature of the pipe and that of the surrounding air. Hence, to find the number of square feet of radiating surface required to heat a given supply of air to a given temperature, multiply the number of cubic feet of air per hour by the difference between the temperature of the cold air-supply and that to which it is to be heated, and divide it by 50; this will give the number of thermal units required; then dividing these by the difference between the temperature of the radiating surface and that of the surrounding air multiplied by 1·75, the number of square feet of surface required will be found.

Artificial Cooling of Air.—Any consideration of the subject of ventilation would necessarily be incomplete if reference were not made to methods for cooling the air, for although, in this country, the general problem of maintaining the air of an inhabited room at a temperature most suitable for its occupants involves the consideration of how to heat the air rather than to cool it, still there are countries and circumstances in which the question of reducing the air temperature is one of paramount importance.

The simplest method to adopt for preventing direct radiation of the sun from entering rooms is to shut doors and windows, and cover them with either blinds or louvre shutters. In countries like India, where the outside air is often excessively dry, it can be cooled by being made to pass over wet surfaces of linen or *tatties* made of khus-khus grass. Some years ago, it was suggested by Jeffreys to supply cooled air to the hospital and barracks at Cawnpore by passing the air, before delivery into the rooms, through underground channels. This, though ingenious, is not a desirable method, as the air is likely to be fouled in its passage beneath the earth, unless very special precautions are taken to keep the channels dry and clean.

Owing to the development of a demand for artificial ice, and the supply of cold air in ships employed for the carriage of meat, a considerable impetus has been given of late years to the invention of machines and methods for artificial cooling. Practically, cold can be produced in one of three ways, namely, (1) by the expansion of air; (2) by the expenditure of mechanical work in the evaporation of a liquid; (3) by the evaporation of a volatile liquid in one vessel, the vapour so formed being absorbed by water or some other liquid in another vessel connected with the first.

(1) The remarkable changes of temperature produced by the rarefaction and condensation of air was pointed out in 1845 by Joule. The following table shows the effect of the dynamical cooling of air by reduction of pressure to 30 inches, from the pressure as stated in the first column, without allowing any heat to be communicated to it during expansion, the original temperature at 30 inches of pressure being 60° F. (Shaw):—

Initial Pressure of the Air in Inches of Mercury.	Temperature after Expansion.	Initial Pressure of the Air in Inches of Mercury.	Temperature after Expansion.
31	55°·1 Fahr.	60	− 33°·9 Fahr.
32	50°·4 "	70	− 52°·4 "
33	45°·9 "	80	− 67°·7 "
34	41°·6 "	90	− 80°·8 "
35	37°·5 "	100	− 92°·1 "
40	18°·7 "	200	− 158°·5 "
50	− 11°·0 "	300	− 191°·6 "

Thus it will be seen that if a jet of air at 60° F. were blown into a room by a pressure behind it of 10 inches of mercury above the ordinary barometric pressure, so that the air would find itself in the room suddenly under the ordinary pressure of 30 inches, the temperature of that air would be 13°·3 F. below freezing, presuming that there is no gain of heat from friction at the nozzle. On this principle it is possible, by means of suitable arrangements of expansion cylinders, to furnish a supply of air cooled by expansion to a temperature considerably below that of the surrounding bodies. If the air were compressed instead of being rarefied, a corresponding rise of temperature would be produced. This principle of dynamical cooling has now been applied to the refrigeration chambers of ships conveying meat from the colonies, where, by first compressing the air in a suitable engine, it is then passed to an expansion engine, which finally delivers the air cooled to an extent depending on the difference of its pressure in the compressed and uncompressed states. It is not improbable that in the near future, with a supply of compressed air at ordinary temperatures and by an expansion engine, every householder may not only get ice-cold air, but so produce ice if wanted. Its applicability to Indian life is obvious, where the use of refrigerating engines, as now employed on board ships for the meat refrigerating chambers, will probably gradually replace the crude and cumbrous thermantidote of the present day.

(2) We know that water evaporates at all temperatures, and that the amount of evaporation really depends upon the pressure to which the surface is exposed. If, therefore, two vessels, each containing a volatile liquid, be in communication through an air-pump, and the pump be worked, any air or vapour in the one vessel will be gradually pumped out and delivered to the other. In other words, continuous evaporation will take place in one vessel, and continuous condensation in the other. As a result of evaporation, there is an absorption of heat from the one vessel, and, as a result of condensation, a development of heat in the other. If an arrangement be made for transferring the condensed liquid back to the evaporating vessel, the process may go on continuously. If heat is wanted, the cold vessel should be surrounded with an ample supply of water to keep up its temperature ; if cooling be desired, the heat produced by the condensation may be allowed to pass into the outside air or a tank of water. The production of cold on this principle by the evaporation of methylic ether is now one of the methods of cooling ships employed in the carriage of meat. By the cooling apparatus, the meat is kept in a current of dry air very near the freezing-point, and thus kept fresh during long voyages.

(3) In Carré's ammonia machine for the production of ice, a solution of ammonia gas in water is placed in a vessel connected with a condenser. If the vessel be heated and the condenser immersed in a cold-water tank, the ammonia is driven off from its solution, and, condensing to a liquid in

the condenser, gives out heat in so doing to the surrounding water in the tank. If the vessel be now immersed in cold water, and the condenser be surrounded by the water it is required to freeze, the cooled water in the vessel reabsorbs the ammonia vapour and reduces the pressure in the condenser, accompanied by a large reduction of temperature in the liquid in it and in the water surrounding it. By a continuous repetition of the process, successive quantities of heat are removed from the water surrounding the condensed ammonia, until it actual freezes. By this method, ice can be made at a cost of only twopence per hundredweight.

EXAMINATION OF THE SUFFICIENCY OF VENTILATION.

The sufficiency of ventilation should be examined:—

First, by determining the amount of cubic space and floor space assigned to each person, and their relation to each other, and by determining the amount of movement of the air, or, in other words, the number of cubic feet of fresh air which each person receives per hour.

Secondly, by examining the air by the senses, and by chemical, biological, and mechanical methods, so as to determine the presence, and, if possible, the amounts and characters of suspended matters, including micro-organisms, organic vapour, carbon dioxide, hydrogen sulphide, watery vapour, ammonia, &c., as already explained in the previous chapter.

Measurement of Cubic Space.—The three dimensions of length, breadth, and height are simply multiplied into each other. If a room is square or oblong, with a flat ceiling, there is, of course, no difficulty in doing this, but frequently rooms are of irregular form, with angles, projections, half-circles, or segments of circles. In such cases the rules for the measurement of the areas of circles, segments, triangles &c., must be used. By means of these, and by dividing the room into several parts, as it were, so as to measure first one and then another, no difficulty will be met. After the room has been measured, recesses containing air should be measured, and added to the amount of cubic space; and, on the other hand, solid projections, and solid masses of furniture, cupboards, &c., must be measured, and their cubic contents (which take the place of air) deducted from the cubic space already determined. The bedding also occupies a certain amount of space; a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets will occupy almost 10 cubic feet—about 7 if tightly rolled up. It is seldom necessary to make any deduction for tables, chairs, and iron bedsteads, or small boxes, or to reduce the temperature of the air to standard temperature, as is sometimes done.

A deduction may be made, however, for the bodies of persons living in the room; a man of ordinary size may take the place of about $2\frac{1}{4}$ to 4 cubic feet of air (say 3 for the average). The weight of a man in stones, divided by 4, gives the cubic feet he occupies. Thus a man weighing 12 stone occupies 3 cubic feet.

In linear measurement, it is always convenient to measure in feet and decimals of a foot, and not in feet and inches. If square inches are measured, they may be turned into square feet by multiplying by 0·007.

RULES—*Area or Superficies.*

Area of circle	$=D^2 \times \cdot 7854$ (or πr^2, where r is the radius).
,, ...	$=C^2 \times \cdot 0796 \left(\text{or } \frac{C^2}{4\pi}\right)$.
Circumference of circle . .	$=D \times 3\cdot 1416$ ($\pi 2r$).

Diameter of circle . . . . $=C \div 3{\cdot}1416 \left(=\frac{C}{\pi}\right)$ or $C= \times {\cdot}3183$.

Area of ellipse . . . . . = Multiply the product of the two diameters by $\cdot7854 \left(\frac{\pi l s}{4}\right)$.

Circumference of ellipse . . . = Multiply half sum of the two diameters by $3{\cdot}1416 \left\{\pi\frac{l+s}{2}\right\}$.

Area of a square. . . . . = Square one of the sides, or multiply any two sides into each other.

Area of a rectangle . . . = Multiply two sides perpendicular to each other.

Area of a triangle . . . . = Base $\times \frac{1}{2}$ height, or Height $\times \frac{1}{2}$ base.

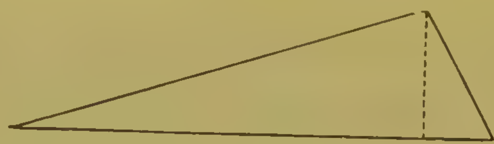


Fig. 22.

Area of a parallelogram . . = Divide into two triangles by a diagonal, and take sum of the areas of the two triangles.

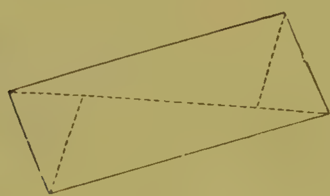


Fig. 23.

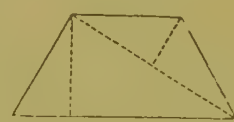


Fig. 24.

Any figure bounded by right lines . = Divide into triangles, and take the sum of their areas.

Area of segment of circle . . = To $\frac{2}{3}$ of product of chord and height add the cube of the height divided by twice the chord

$$(Ch \times H \times \tfrac{2}{3}) + \frac{H^3}{2Ch}.$$

Fig. 25.

Cubic Capacity of a Cube or a Solid Rectangle.—Multiply together the three dimensions length, breadth, and height.

Cubic Capacity of a Solid Triangle.—Area of section (triangle) multiplied by depth.

Cubic Capacity of a Cone or Pyramid.—Area of base $\times \frac{1}{3}$ height.

Cubic Capacity of a Dome.—Two-thirds of the product of the area of the base multiplied by the height (area of base $\times$ height $\times \frac{2}{3}$).

Cubic Capacity of a Cylinder.—Area of base $\times$ height.

Cubic Capacity of a Sphere.—$D^3 \times \cdot5236 \left(\text{or } \frac{4\pi r^3}{3}\right)$.

The cubic capacity of a bell-tent may be taken as that of a cone resting on a short cylinder.

The cubic capacity of a hospital marquee must be got by dividing the marquee into several parts—(1) body; and (2) roof:—

(1) Body, as a solid rectangle, with a half-cylinder at each end.

(2) Roof, solid triangle, and two half-cones.

The total number of cubic feet, with additions and deductions all made, must then be divided by the number of persons living in the room; the result is the cubic space per head; whilst the total area of floor space divided by the number of persons gives the floor space per head, which should be as near as possible $\frac{1}{12}$th of the cubic space.

Determination of Air Movement in a Room.—The direction must first be determined, and then the rate of movement.

First enumerate the various openings in the room—doors, windows, chimney, special openings, and tubes—and consider which is likely to be the direction of movement and whether there is a possibility of thorough movement of the air. Then, if it is not necessary to consider further any movement through open doors or windows, close all these, and examine the movements through the other openings. This is best done by smoke disengaged from smouldering cotton-velvet, and less perfectly by small balloons, light pieces of paper, feathers, &c. The flame of a candle, which is often used, is only moved by strong currents. It may be generally taken for granted that one half of the openings in a room will admit fresh air, and half will be outlets. But this is not invariable, as a strong outlet, like a chimney, may draw air through an inlet of far greater area than itself, or may draw it through a much smaller area with an increased rapidity.

The direction being known, it is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter.

By the Anemometer.—This is carried out by means of an airmeter, of which there are several in the market. The one commonly used is in principle that invented by Combes in 1838; four little sails, driven by the moving air, turn an axis with an endless screw, which itself turns some small toothed wheels; these indicate the number of revolutions of the axis, and consequently the space traversed by the sails in a given time, say one minute. By a careful graduation of each instrument, the rate per second is determined, and indicated by a small dial and index. An elegant instrument of this kind has been made by Casella (Fig. 26). It is thus used :—Being set at the zero point, or the reading of the instrument at the time being recorded, it is placed in the current of air ; if it is placed in a tube or shaft, it should be put well in, but not quite in the centre, as the central velocity is always greater than that of the side ; a point about two-fifths from the sides of the tube will give the mean velocity. The time when the sails begin to move is accurately noted, and then, after a given time, the instrument is removed, and the movement in the time noted is given by the dial. If this linear discharge is multiplied by the section area of the tube or opening the cubic discharge is obtained. If the current varies in intensity, the movement should be taken several times, and the mean calculated ; but if the tube is so small that the sails approach closely to the circumference, the results cannot be depended on. If placed at the mouth of a tube, it often indicates a much feebler current than really exists in the tube.

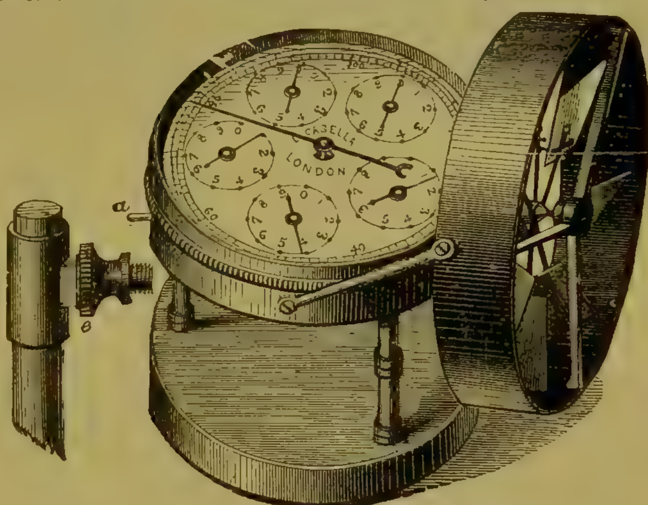


Fig. 26.—Airmeter or Anemometer.

The cubic discharge per minute being known, the amount per hour is obtained by multiplying by 60, and this, divided by the number of persons in the room, gives the discharge per head for that particular aperture.

By Calculation.—Supposing the external air is tranquil, and that the only cause of movement is the unequal weights of the external colder and the internal warmer air, the amount of discharge may be approximately

obtained by the law of Montgolfier, already given. There is a fallacy, however, as the amount of friction can never be precisely known. Still, as an approximation, and in the absence of an anemometer, the rule is useful.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

It is obvious that, in the preceding methods, all windows and doors opening into the room must be closed, and only those openings intended for the passage of air be allowed to remain open.

To make any ventilation inquiry complete, supplementary observations would need to be made, not only as to the carbon dioxide, but also as regards oxidisable and organic matter, as well as to humidity, temperature, suspended matter, micro-organisms, and the various other details mentioned when considering the practical examination of air. When these final analyses have been made, the amount of air per head per hour, supplied and utilised, can be readily calculated as before explained, and compared with the amount of movement determined by the anemometer. If the quantities accord fairly, the distribution may be considered good ; on the other hand, if they differ, an excess by the airmeter shows bad distribution, whilst a deficiency indicates some other source of incoming air not yet observed.

CHAPTER V

FOOD

In the widest acceptation of the term, Food includes everything ingested which goes directly or indirectly to the growth or repair of the body or to the production of energy in any form. In this way it would include not only those organic and mineral solids and the usual beverages recognised as dietetic, but also water and air. For it is quite obvious that without water no function of the living body would be possible, whilst the production of energy is mainly, if not entirely, caused by the union of the atmospheric oxygen with the organic matter of the food or the tissues of the body itself. Although these facts are distinctly recognised, it has generally been the practice to restrict the term " food " to those substances which are capable of oxidation and those which act as directors or regulators of nutrition to the exclusion of air and water—these two last being usually considered under separate heads. No one group even of this rough classification is capable of sustaining healthy life alone, and a combination of all, or nearly all, the different constituents of diet is required to accomplish the best results.

The enumeration and classification of the foods or aliments necessary to maintain human life in its most perfect state have been usually based on the deduction that milk contains all the necessary aliments and in the best form. The substances in milk are—1st, the nitrogenous matters, viz., the casein principally, and, in smaller quantities, albumin, lacto-protein, and perhaps other protein bodies ; 2nd, the fat and oil ; 3rd, sugar in the form of lactose ; 4th, water and salts, the latter being especially combinations of magnesium, calcium, potassium, sodium, and iron, with chlorine, phosphoric acid, and, in smaller quantities, citric acid.

In addition to their occurrence in milk, which is admitted to be a perfect food for the young, this enumeration of aliments appears to be justified by two considerations. First, that the different members of each class, *inter se*, have a remarkably similar composition, while there are broad lines of physical and chemical demarcation between the classes ; and secondly, that the different classes appear to serve different purposes in nutrition, and are all necessary for perfect health.

The various substances which constitute food are conveniently spoken of as *proximate principles*, because, consisting as they do of carbon, hydrogen, oxygen, and nitrogen, combined more or less into highly complex bodies, they really are elementary constituents or proximate principles of the human organism. These elementary or proximate principles may be conveniently classified as follows :—

Organic	Nitrogenous, as proteins or albuminoids.	
	Non-nitrogenous	Fats or hydrocarbons.
		Starches and sugars or carbo-hydrates.
		Vegetable acids.
Inorganic . . .	Mineral salts.	
Food accessories . .	Such as tea, coffee, &c.	

It must be noted that the simplest division of the organic constituents of food is into the nitrogenous and the non-nitrogenous, or those which contain nitrogen and those which do not. Now, the proteins alone contain nitrogen. Just as the greater part of the air is made up of nitrogen, so is the greater part of our body (bone excepted) made up of protein, or nitrogen-containing substances. A large amount of nitrogen in the form of urea, uric acid, and other substances, is being lost daily from our bodies by the urine; and to repair this loss, a daily intake of nitrogenous food is required. The only form of nitrogen food which the body can make use of is that of protein or albuminoids. A plant equally needs nitrogen, but this it obtains from the ammonia and nitrates of the soil, which are much simpler bodies than proteins.

Proteins may be regarded as the most important food-stuffs, as they are the only organic food-substances of which it can be said with certainty that they are indispensable, and that they cannot be replaced by any other nutrient material. They are to be found in every animal and vegetable tissue, forming the chief part of every cell, and are never absent from any vegetable or animal food.

All proteins resemble each other in being composed, in similar weight proportions, of carbon, hydrogen, oxygen, nitrogen, and sulphur, with occasionally a little phosphorus. Their general percentage composition may be taken as being :—nitrogen, 16 parts; carbon, 54 parts; oxygen, 22 parts; hydrogen 7 parts; and sulphur, 1 part. Although the chemical constitution of the protein molecule is still a matter of doubt, our increased knowledge of its cleavage products indicates it to be both large and complex. In the alimentary canal, various proteolytic ferments, acting by a process of hydrolysis, split the protein molecule into proteoses, then peptones and finally into simple products, such as the mono-amino acids glycin, alanin, leucin, asparagin, and aspartic acid, or the di-amino acids ornithin, arginin and lysin, or aromatic amino acids like tyrosin, or certain nitrogenous derivatives of the benzene ring, like indol, skatol and cystin. These substances represent various nuclei which exist preformed in the protein molecule, and are then linked in more or less complicated groups. During proteolysis, some of these groups can be detected, notably the combinations of the amino acids which Fischer has termed polypeptides. The polypeptides are broken down ultimately into the amino acids of which they are composed, and practically occupy a position intermediate between the proteoses and peptones on the one hand, and the final product on the other. In addition to these nitrogenous products, carbo-hydrate groups have been obtained from several albumins. Another degradation product is always, of course, ammonia, but the true significance of amide nitrogen is still unknown. The chief products derived from the oxidation of these cleavage groups within the body are carbon dioxide, water and urea, which latter contains nearly all the nitrogen of the proteins.

The chief character of proteins is that they are colloids, and, therefore, do not diffuse easily through animal membranes; they are also amorphous and do not crystallise, hence are isolated with difficulty. Some are soluble, others are insoluble in water; they are insoluble in alcohol and ether, rotate polarised light to the left, and when burned give off an odour of burned horn. They are precipitated from their solution by various metallic salts and alcohol; they are coagulated by heat, mineral acids, and the prolonged action of alcohol. Caustic alkalies dissolve them, and from this solution they are precipitated by acids.

Chemically, the proteins can be recognised by the following reactions:—

1. Add a few drops of strong nitric acid; boil, the liquid turns yellow; cool, and add ammonia, the yellow liquid turns orange. It is this coloration which is the essential part of the reaction. It is the most delicate test for proteins, being generally called the xantho-proteic reaction.

2. With nitrate of mercury, they give a precipitate, and when heated with this re-agent above 60° C. they give a red one, probably owing to the formation of tyrosin.

3. The addition of a few drops of a dilute solution of cupric sulphate, and the subsequent addition of caustic potash, gives a violet colour which deepens on boiling. If ammonia be used a blue solution is the result. In the case of albumoses and peptones, however, the result is a rose-red solution with potash and a reddish-violet solution with ammonia. This is termed the biuret reaction.

4. When rendered strongly acid with acetic acid and boiled with an equal volume of a concentrated solution of sodic sulphate they are precipitated. This method is used for removing proteins from various liquids, as it is not interfered with by the presence of other substances.

Saturation with sodio-magnesic sulphate precipitates the proteins but not peptones, and the same is the case if saturated with neutral ammonium sulphate.

The proteins, when regarded as foods, are divisible into two great groups according to their nutritive value. The more nutritious one is the group of true proteins, consisting of albumin, myosin, glutin, legumin, casein, globulin, syntonin, and fibrin; in them the proportion of nitrogen to carbon is nearly as 2 is to 7. The other, or less nutritious class, is sometimes called the albuminoid group; its members include substances obtained only from animals, such as gelatin, chondrin, ossein, and keratin; in these latter, the proportion of nitrogen to carbon is as 2 is to 5½.

The difficulties in the way of making an accurate or concise classification of the proteins are great. A great change is coming over our chemical conceptions of these substances, and when E. Fischer's work upon them is concluded some finality in nomenclature will be possible. As an attempt to obtain temporary uniformity in terminology a Joint Committee of the Physiological and Chemical Societies of England has suggested * that the word "protein" be used to express the whole group, and that the term proteid be abolished or restricted to a sub-group corresponding to the conjugated proteids of the Germans. Under this suggested classification and nomenclature, the various sub-classes of the proteins, beginning with the simplest, would be as follows: (1) protamines, represented by such substances as salmine and clupeine; (2) histones, represented by the globin of blood and lymph cells; (3) albumins; (4) globulins; (5) sclero-proteins, represented by gelatin, keratin, &c., and corresponding to the old group known as albuminoids—the prefix indicates the skeletal origin and often insoluble nature of its members; (6) phospho-proteins represented by the vitellin-caseinogen group; and (7) conjugated proteins, in which the protein molecule is united to a prosthetic group:—(*a*) gluco-proteins, such as mucin; (*b*) nucleo-proteins, and (*c*) chromo-proteins such as hæmoglobin. The products resulting from protein hydrolysis are classified into:—(1) infra-proteins, formerly called acid and alkali albumins; (2) proteoses, including albumose, globulose, gelatose, &c.; (3) peptones or substances which cannot be salted out from solution, but which still give the biuret reaction; and (4) polypeptides or

* Halliburton: "Proteid Nomenclature," *Brit. Med. Journal*, September 8, 1906, p. 551; also *The Essentials of Chemical Physiology*, London, 1907. *See also* a paper by Barker on "Amino-acids and Metabolism," *Brit. Med. Journal*, October 27, 1906, p. 1093.

compounds resembling peptones but not giving as a rule the biuret reaction. Fibrin, being a derivative of fibrinogen, and the latter a globulin, is placed among the globulins. It is, finally, suggested to continue to use the words caseinogen, casein, paramyosinogen and myosinogen.

Fats or Hydrocarbons.—These are combinations of a trivalent alcohol, glycerin, with three molecules of monobasic acids, principally stearic acid, palmitic acid, and oleic acid. They all contain hydrogen and oxygen, but no nitrogen, and may be represented by the general formula $C_{10}H_{18}O$. The proportion of oxygen in them, however, is insufficient to combine with all the hydrogen present so as to form water. When taken as food, the fats are chiefly in the form of neutral fat, but may also exist in the form of fatty acids and of their compounds, the alkaline soaps. The neutral fat taken as food always contains free fatty acids in greater or less proportion, and in some foods, such as cheese, the fatty acids may exist in large proportions indeed.

Carbo-hydrates occur in plants and animals, and are so called because, in addition to at least six atoms of carbon, they contain hydrogen and oxygen in the proportion in which these occur in water. They are all solid, chemically indifferent, and without odour. They have either a sweet taste (sugars) or can be readily changed into sugars by the action of dilute acids; they rotate the ray of polarised light either to the right or left, and, as far as their chemical constitution is concerned, may be regarded as hexatomic alcohols in which two atoms of hydrogen are wanting. Until recent times the true chemical nature of these bodies was not understood, but the researches of E. Fischer have shown that the simplest carbo-hydrates (the old grape-sugars or glucoses) are aldehydes of a hexatomic alcohol, having the formula $C_6H_8(OH)_6$. Just as during the oxidation of ordinary alcohol, C_2H_6O, the aldehyde C_2H_4O is formed, so from mannitic alcohol the molecule $C_6H_{12}O_6$, representing the simplest carbo-hydrate, is produced. Such carbo-hydrates are spoken of as *Monosaccharids*, and the best known are glucose, lævulose, and galactose.

These monosaccharid molecules may link together (polymerise) with the loss of water. When two such molecules thus unite, *Disaccharids* are produced, and these really split to yield their constituent monosaccharids. The most important of these are maltose, formed from two molecules of dextrose, and cane-sugar, formed from a molecule of dextrose connected to a molecule of lævulose, and milk-sugar or lactose, in which dextrose and galactose are linked together.

Further combination (polymerisation) and dehydration produces a set of bodies having molecules of increased size. The simpler members of this series, or those most nearly resembling the sugars, are the dextrins, while among the more complex are starch and glycogen. The whole series may be conveniently called *Polysaccharids*. In some of the higher members of the group, such as the starches, more than a hundred monosaccharid molecules may be connected together. These polysaccharids tend to break down into their constituent disaccharid and monosaccharid molecules. A comprehension of these facts is essential for a study of the changes which these food-substances undergo in the animal body.

In the first group, or the monosaccharids, we have the following:—

Grape-sugar, $C_6H_{12}O_6$ (glucose, dextrose or diabetic sugar), when occurring in animal tissues, is mainly formed by the action of diastatic ferments upon other carbo-hydrates during digestion. In the vegetable kingdom it is extensively distributed in the sweet juices of many fruits and flowers. It is formed from cane-sugar, maltose, dextrin, glycogen, and starch by boil-

ing them with dilute acids. By fermentation with yeast, it splits up into alcohol and CO_2; with decomposing proteins it splits into two molecules of lactic acid, while this latter, under the same conditions in alkaline solutions, splits up into butyric acid, carbon dioxide and hydrogen.

Galactose is obtained by boiling lactose or milk-sugar with dilute mineral acids; it crystallises, is fermentable and gives all the reactions of glucose. Its specific rotatory power is $+83^\circ{\cdot}3$ for A_j or median yellow ray of light.

Lævulose, sometimes called *invert* sugar, occurs as a colourless syrup in honey and juices of some fruits. It is non-crystallisable, and rotates -106° for A_j.

In the second group, or disaccharids, we have carbo-hydrates which may be regarded as anhydrides of the monosaccharids, with the formula of $C_{12}H_{22}O_{11}$. Thus, *Lactose* or milk-sugar occurs only in milk. It rotates polarised light $+61^\circ{\cdot}5$ for A_j, and is much less soluble in water and alcohol than grape-sugar. When boiled with dilute mineral acids, it passes into galactose, and can be directly transformed into lactic acid only by fermentation; the galactose, however, is capable of undergoing alcoholic fermentation with yeast (koumiss).

Maltose has one molecule of water less than grape-sugar, and is the final product of the action of diastase on starch. It has a rotatory power of $+150^\circ$, and is soluble in alcohol.

Cane-sugar or saccharose occurs in sugar-cane and some plants; it does not reduce a solution of copper, is insoluble in alcohol, is right rotatory, $73^\circ{\cdot}8$ for A_j. With yeast it is first inverted by means of a special soluble ferment produced by the yeast cell, followed by an alcoholic fermentation of the glucoses so formed. When boiled with dilute acids, it becomes changed into a mixture of glucose and lævulose (invert sugar).

In the third group we have carbo-hydrates with the formula, $nC_6H_{10}O_5$, which may be regarded as anhydrides of the second group. The chief among them are:—

Starches, which constitute the chief portion of the seeds of the various cereals and potatoes. Starch combines with iodine to form a blue colour, constituting thereby a simple test for its presence. In cold water or alcohol starch is insoluble, but at 72° C. (161°·6 F.) it swells up in water and forms a mucilage. Starch-grains always contain more or less cellulose and a substance, erythrogranulose, which is coloured red with iodine. Heat and dilute acids, also the digestive ferments in the saliva, pancreatic and intestinal juices, convert starch into a gum-like substance, called dextrin, and if carried further into grape-sugar.

Glycogen, or the so-called animal starch, has a dextro-rotatory power of 211°, and does not reduce cupric oxide. It occurs in the liver, muscles, and various other tissues of man and animals. It occurs also in the oyster and some other molluscs.

Dextrin occurs in beer, and in the juices of most plants. In water, it forms a sticky solution, from which it is precipitated by alcohol or acetic acid; it also slightly reddens with iodine. Dextrin is largely present in the crust of bread, and if examined with polarised light in dilute solutions, rotates $+138^\circ{\cdot}88$ for A_j. It is further formed from cellulose by the action of dilute sulphuric acid.

Among carbo-hydrates of this group must be included cellulose and pectose. *Cellulose* constitutes the chief framework of plants; it is quite insoluble, and apparently without any dietetic value. When boiled with dilute sulphuric acid, it yields dextrin and glucose. In a similar way, *pectose* or vegetable jelly is found in various ripe fruits, being really a later

stage of the insoluble body present in most unripe fruits, and known as pectin. Its precise composition is unknown.

Vegetable Acids.—These, though not, strictly speaking, foods, play so important a part in preserving the health of man that they demand some considerable notice. The chief among them are tartaric, citric, malic, oxalic, and acetic acids. *Tartaric acid*, $C_4H_6O_6$, exists largely in grape-juice chiefly as the acid tartrate of potassium; *Citric acid*, $C_6H_8O_7$, is found in oranges, lemons, and gooseberries; *Malic acid*, $C_4H_6O_5$, is met with in fruits belonging to the rose order, such as apples and pears; *Oxalic acid*, $C_2H_2O_4$, is present largely in rhubarb and sorrel; *Acetic acid*, $C_2H_4O_2$, constitutes the active element in vinegar. Except it be the latter, all these vegetable acids contain more than sufficient oxygen to convert all their hydrogen into water. These acids exist mainly in fresh fruits and vegetables, either as free acids or in combination with alkalies as alkaline salts, and, when taken into the body, form carbonates, which exercise a controlling influence in preserving the alkalinity not only of the blood but other fluids; they also furnish a small amount of energy and heat by oxidation. Their absence for any length of time from any dietary leads to an altered condition of the blood, associated with the causation of scurvy. It is possible that some of these acids are not only derived from fruits and vegetables, but also in a small degree from the splitting up of carbo-hydrates, so that even the latter, in an indirect way, help in maintaining the alkalinity of the blood and other animal fluids.

Mineral Salts.—Among the mineral salts which constitute a part of the proximate principles of food must be included chloride of sodium or common salt, the phosphates of lime, potash, soda, and magnesium, along with small quantities of sulphates and possibly iron. These, in their various and respective ways, are essential for the repair and growth of all parts of the body. The uses of the chlorides, as typified by common salt, are very important. The complete withholding of ordinary salt from food leads to rapid disease and even death. The chlorides generally keep in solution the globulins of the blood and other fluids, while at the same time they are the source of the hydrochloric acid of the gastric juice, and materially aid in the solution of albumin. The phosphates of lime, potash, and magnesia contribute, especially in the young, to the formation of bone; while iron forms an important part of the hæmoglobin of the red blood-corpuscles.

THE NUTRITIVE FUNCTIONS OF THE FOOD-STUFFS.

The physiological evidence that these classes of aliments serve different purposes in nutrition is not so complete as that of their chemical differences.

A broad distinction must, of course, be drawn between the nitrogenous and non-nitrogenous substances. Modern researches, which have much modified our opinion of the direction in which the potential energy of the dietetic principles may be manifested, and of the mode in which the nitrogenous substances in particular aid or restrain this transformation, do not impeach the proposition that the presence of nitrogen in an organised structure, and its participation in the action going on there, is a necessary condition for the manifestation of any energy or any chemical change. Whether, when energy is manifested, the nitrogenous framework of any nitrogenous structure is a mere stage on which other actors play, or whether it is used up and destroyed, or is, on the other hand, built up or renovated during action, is, so far as classification of food is concerned, a matter of no consequence.

Protein food contains those elements of which the essential tissues and organs of the body are made; it is, therefore, an essential food-stuff. The manifold activities of living protoplasm are only equalled by the bewildering complexities of the molecular groups composing it. By the act of digestion, these groups are separated from each other, and such as are needed for the reconstruction of tissue are built up again into protoplasm, while any excess taken is converted into urea and excreted within a few hours. The following considerations prove the necessary participation of the nitrogenous structures in manifestations of energy. Every structure in the body capable of manifesting energy is nitrogenous. The nerves, the muscles, the gland cells, the floating cells in the various liquids, the semen and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen, in order that these actions shall be performed; and the same constancy of the presence of nitrogen when function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. Then, if the nitrogen be cut off from the body, the various functions languish. This does not occur at once, for every body contains a store of nitrogen, but it is at length inevitable. Again, if it is wished to increase the manifestation of the energies of the various organs, more nitrogen must be supplied. All physiological experiments show that the nitrogenous substances composing the textures of the body determine the absorption of oxygen.

The absorption of oxygen does not determine the changes in the tissues, but the changes in the tissues determine the absorption of oxygen. In other words, without the participation of the nitrogenous bodies, no oxidation and no manifestation of energy is possible.

When any quantity of protein has been digested there is an early excretion of urea, that is, within twenty-four hours an amount of nitrogen corresponding to that ingested appears in the urine, except in such cases as are laying on flesh. This fact suggests that the protein taken in has not been built up into body tissue, and thus the view forces itself upon us that this rapidly excreted nitrogen is not needed by the body for structural purposes, and hence the protein containing it is hydrolysed and the nitrogen is excreted. The rapidity with which the elimination of nitrogen takes place is explained when we consider the probability that proteins are absorbed, not as peptone, but as amido-bodies and other simpler cleavage products, the hydrolysis of the parent protein molecule taking place chiefly in the intestine, and that such a proportion of these absorbed substances as is not needed to build up tissue is not reconverted into protein at all but turned at once, as regards its nitrogenous moiety, into urea. Albumoses, peptones and the various fractions obtained by digestion have been shown to be capable of keeping the body in nitrogenous equilibrium, but metabolic experiments show, however, that these substances are far from being desirable, from a dietetic point of view, either in health or disease.* Folin says that kreatin given in moderate quantities with a low nitrogen diet is not eliminated at all; given in large quantities (from 5 to 6 grains) with a low nitrogen diet, about 1 grain is eliminated unchanged, while if it be given along with food rich in protein some 50 per cent. is excreted unchanged within twenty-four hours. The fate of the non-nitrogenous carbon-containing moiety of the protein molecule is not definite, but it is oxidised probably to

* Spriggs: "The Bearing of Metabolism Experiments upon the Treatment of some Diseases," *Lancet*, April 28, 1906, p. 1154.

furnish energy in the same way as fat or carbo-hydrate. This view suggests that any excess of protein may be replaced by fat or carbo-hydrate, which, while serving equally well for the production of energy by oxidation, would not throw upon the excretory organs the work of eliminating so much nitrogenous material. As we shall see later, experiment bears this out.

The proteins are further a source of fats and possibly of carbo-hydrates, so that they really play two parts, first, that of regulators of oxidation and of the transformation of energy; and second, they may form a non-nitrogenous substance which is oxidised and transformed. That fats are formed from proteins is shown by the following:—(1) Carnivora giving suck, when fed on plenty of flesh and little fat, yield milk rich in fat. (2) A cow which produces one pound of butter daily does not take nearly this amount of fatty matter in her food, so that the fat would appear to be formed in this case from vegetable proteins.

That the proteins are a source of carbo-hydrate also, is shown by the fact that, in an animal deprived of glycogen by strychnine poisoning, this carbo-hydrate appears again in the liver and muscles under the influence of chloral, even though the animal is starved. As to how this is brought about, considerable diversity of opinion prevails. The question practically is, does the protein molecule contain carbo-hydrate molecules which are set free when it breaks down; or do the elements of the protein molecule, after breaking down and then becoming part of the protoplasm, change into the carbo-hydrate molecule? According to Pflüger, the latter is the probable explanation, while Pavy attempts to furnish evidence that the protein molecule does contain a carbo-hydrate moiety, which is the source of carbo-hydrates formed from proteins. No matter which view is correct, the fact that proteins are a partial source of both fats and carbo-hydrates, must not allow us to consider a protein as an aliment which may replace fat or starch or sugar in the case of man. The digestive system of man is framed so differently from that of the carnivora, that fat must be taken in its own form, for it either cannot be formed in sufficient quantity from proteins, or the body is poisoned by the excess of nitrogen which is necessarily absorbed to supply it.

The use of **fats** in the organism is that they are sources of energy and of heat to the body. In the majority of national dietaries fat finds a place, and in some cases, as that of the Esquimaux, it is greatly increased in the dietary. When hard work is to be done, an excess of fat is involuntarily taken. Whatever the mixture of fats taken in as food, the fat of the body always has the same composition; this fact agrees with the conclusion that the deposition and metabolism of fat in the body is due to cell activity, and that the fat comes in part from the protein, and part from the carbo-hydrate foods.

The consumption of **carbo-hydrates** spares not only protein food, but also fat. They lessen the need of fat by being a source of energy in the body, and thus when present in a diet poor in fat, they diminish the oxidation of fat in the body. The experiments of E. Smith, Haughton, and others, on muscular action, prove that we must look for the main source of energy which is apparent during muscular action in the oxidation of the non-nitrogenous substances, but no experiments have yet shown whether these are fats or carbo-hydrates. It seems to be inferred that it is fat which is thus chiefly acted upon, but this opinion is rather derived from a reference to the universal presence of fat when energy is manifested, to the known necessity of it in diet, and from the large amount of energy its oxidation can produce than from actual observation. If it were true, a broad dis-

tinction would be at once drawn between fatty and starchy food, but it is not experimentally proved. If, on the other hand, it were certain that the starchy aliments formed fat in the human body, as a rule, this would be a reason for drawing no distinction between the groups. Independent of the argument drawn from bees fed on sugar alone and forming wax, from the fattening of ducks and geese, and the older experiments on pigs, the later experiments of Lawes and Gilbert seem to show clearly that the fat stored up in fattened pigs cannot be derived from the fat given in the food, but must have been produced partly from nitrogenous substances, but chiefly from the carbo-hydrates. So also it seems now probable that the fat in milk is not derived at once from blood, but from changes of albumin in the lacteal gland cells. There seems no reason why we should not extend the inference to man. If so, a man could live in perfect health on a diet composed only of fat-free meat and starch, with salts and water, just as he can certainly live (though perhaps not in the highest health) on meat, fat, salts, and water. The carbo-hydrates would then be proved to be able to replace fats. The experiment has not yet been performed, or at least recorded, but it seems important it should be.

Many authorities state that fat is formed *directly* from carbo-hydrates, and the weight of evidence appears to favour this view; but whether it is so formed directly, or indirectly, by retarding the metabolism of the fatty and protein constituents of the food, there is no doubt that the consumption of carbo-hydrates results in the formation of fat within the body.

Grouven's experiments also suggest that in cattle the carbo-hydrates may split up in the alimentary canal into glycerin, lactic and butyric acids, with carbon dioxide and marsh gas. If this be true, in the herbivora the starches would be merely another form of fat.

In man it has been pointed out that, as fermentative changes occur in the small intestines with the production of lactic acid, so the butyric acid fermentation may possibly take place in the sugar of the intestinal contents. By this change the sugar would be removed from the carbo-hydrate group into the fatty acid group, and, as Foster says, "put on its way to become fat."

The possibility of the conversion of fats to carbo-hydrates in the animal body has so far not been fully investigated. Seegen has suggested that fats do yield sugar in the body, but his experiments are unsatisfactory. The glucoside constitution of protein matter, and the partial origin of carbo-hydrates from proteins, as advanced by Pavy, has already been mentioned; he further maintains that the carbo-hydrates, stored as glycogen, or as they pass through the intestinal wall, go to form protein. Possibly he is right; but to argue, as he does, from plants to animals is somewhat dangerous. Though asparagin and carbo-hydrates may be built into the protoplasm molecules of plants, the direct experimental evidence against the utilisation of the former substance in animals is very strong. His further view that carbo-hydrates are changed to fats is in conformity with the results of many experimenters, though how this actually takes place is not quite so clear.

As to the changes which the carbo-hydrates of food undergo in the alimentary canal, the most recent research has demonstrated the important action of the intestinal secretions in bringing about the complete conversion of polysaccharids and disaccharids to monosaccharids. Starches and maltose are entirely converted to dextrose, while cane-sugar is split into dextrose and lævulose. It is probable that the conversion of starch is not always completed before absorption, and that some of the lower dextrins may pass

through the intestinal wall along with dextrose. Cane-sugar, too, when in excess, may escape conversion and pass into the blood as such. On the other hand, milk-sugar does not appear to be acted upon except by the intestinal bacteria, which split it up in part to lactic acid, &c.

An argument against the fats and carbo-hydrates being mutually replaceable under ordinary conditions in the diet of men is drawn from a consideration of the diets used by all nations. In no case in which it can be obtained is an admixture of starch, in some form, with fat omitted. Moreover, in all cases (except in those nations, like the Esquimaux, who are under particular conditions of food) we find that the amount of fat taken is comparatively small as compared with that of starches. The fats when taken into the body enter like the proteins into the structure of the tissues, of which fat forms in probably all cases an essential part. The carbo-hydrates, on the other hand, in the human body do not appear to be part of the tissues, though they are contained in the fluids which bathe them, or are contained in them. The special direction which the chemical changes in the carbo-hydrates take in the body seems also to point to special duties. Thus, the formation of lactic and other acids of the same class must arise from carbo-hydrates chiefly or solely. But the formation of these acids is certainly most important in nutrition, for the various reactions of the fluids, which offer so striking a contrast (the alkalinity of the blood, the acidity of most mucous secretions, of the sweat, urine, &c.), must be chiefly owing to the action of lactic acid on the phosphates, or the chlorides, and to the ease with which it is oxidised and removed. If the direction of the changes which the carbo-hydrates undergo within the body is different from that of the fats, the products of these changes must be inferred to play dissimilar parts.

Without pushing these arguments too far, and with the admission that the subject is still obscure, we are fairly entitled to assert that the two groups of fats and carbo-hydrates are not so immediately and completely convertible as to permit us to place them together in a classification of diets.

The **salts** and **water** are as essential as the nitrogenous substances. Lime, chiefly in the form of phosphate, is absent from no tissue; and there is reason to think no cell growth can go on without it; certainly, in active morbid growths, and in rapidly growing cells, it is in large amount.

When phosphate of calcium was excluded from the diet, the bones of an adult goat were not found by H. Weiske to be poorer in lime, because probably lime was drawn from other parts; but the goat became weak and dull, so that nutrition was interfered with. Experiment has shown that the growth of wheat is more quickly and effectually checked by the absence of phosphoric acid than of any other constituent from the soil. The lowest forms of life will not grow without earthy phosphates.

Magnesia is probably also an essential constituent of growth in some tissues. Potash and soda, in the forms of phosphates and chlorides, are equally important, and would seem to be especially concerned in the molecular currents; forming parts of almost all tissues, they are less fixed, so to speak, than the magnesian and lime salts. It is also now certain that the two alkalies do not replace each other, and have a different distribution; and it is so far observable, that the potash seems to be the alkali for the formed tissues, such as the blood cells or muscular fibre; while the soda salts are more largely contained in the intercellular fluids which bathe or encircle the tissues.

The chlorine and phosphoric acid have also very peculiar properties—the former apparently being easily set free, producing an acid which has a special action on proteins, and plays a necessary part in maintaining

the globulin in solution; the latter has remarkable combining properties with alkalies. Both are furnished in almost all food; the sodium chloride also separately. Carbonic acid is both introduced and made in the system, and probably serves many uses. Iron is, of course, also essential for certain tissues or parts, especially for the red blood-corpuscles, and for the colouring-matter in muscle, and in small quantity is found almost in every tissue and in every food. The sulphur and phosphorus of the tissues appear to enter especially as such with the proteins.

Some salts, particularly those which form carbonates in the system, such as the lactates, tartrates, citrates, and acetates, give the alkalinity to the system which seems so necessary to the integrity of the molecular currents. The state of malnutrition, which in its highest degree we call scurvy, appears to follow inevitably on their absence; and, as they exist chiefly in fresh vegetables, it is a well-known rule in dietetics to supply these with great care, though their nutritive power otherwise is small. So important are these substances that they might well be placed in a separate class, although Pavy remarks that "these principles are hardly of sufficient importance, in an alimentary point of view, to call for their consideration under a distinct head." Surely this is an under-estimate of their importance, considering the inevitable malnutrition that follows on their absence.

In addition to the substances composing these four classes, there are others which enter into many diets, and which have been termed "accessory foods." The various condiments which give taste to food, or excite salivary or alimentary secretions, and tea, coffee, cocoa, alcohol, &c., furnish the chief substances of this class. Much discussion has taken place as to the exact action in nutrition of these substances, but little is definitely known.

With regard to the necessity of all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of proteins, fat, salts, and water. But special conditions of life, such as great exercise, or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such a diet. It has not yet been shown that men can live in good health on proteins, carbo-hydrates, salts, and water, &c., without fat.

The exact effect produced by the deprivation of any one of these classes is not known. An excess of the proteins causes a more rapid oxidation of fat, while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminous tissues. The carbo-hydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

It is generally admitted that the success of Banting's treatment of obesity is owing to two actions:—the increased oxidising effect on fat consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of the starches.

Health cannot be maintained on proteins, salts, and water alone; but, on the other hand, it cannot be maintained without them.

THE NUTRITIVE VALUE OF FOOD-STUFFS.

In the preceding section we have learnt the part the various food-stuffs play when taken into the body; it is now necessary to learn their nutritive value. To begin with, if we lift a weight by our hands, muscular force is

employed in the act, and the energy evolved in this or any other muscular action must have its origin or source in something. As a matter of fact, the energy so evolved has its source in the material which has been supplied to the body in the form of food. Every process of our bodies, no matter whether it be the moving of a hand or a foot, the beating of our heart, or the secretion of saliva, is attended with some manifestation of energy, and this energy is shown in one or other of two forms, namely, either mechanical labour or heat. These facts will be more clearly understood if it is borne in mind that what is called *energy* in an agent is merely an expression that that agent is capable of doing work, and that the quantity of energy it possesses is measured by the amount of work it can do. An agent or force is said to do work when it produces any change in the condition of bodies; therefore energy is the capacity for producing physical change. This capacity for producing change or energy is of two kinds, namely, *kinetic energy* or the energy of movement, and *potential energy* or that of position. This latter term denotes various forms of energy which are suspended in their action, and which, although they may cause motion, are not in themselves motion. Thus, a coiled watch-spring possesses energy of position or potential energy, and only wants a touch to transform the energy of position into energy of movement, or potential into mechanical energy. Moreover, this transformation of potential into kinetic energy, or *vice versâ*, can take place without any part of the energy being lost, and it is further possible to convert the whole of the energy possessed by any body into heat. Thus if a piece of lead be thrown from a high tower to the ground, and if it strike some hard, unyielding substance, the movement of the lead mass is not only arrested but its kinetic energy is transformed into violent vibratory movements of the lead atoms. As a result of this violent vibration of atoms, heat is produced, and the amount of this is proportional to the kinetic energy of the lead, which again was proportional to its potential energy when in position on the tower. In the human body the ordinary movements of the whole system and of individual organs are constantly being transformed into heat. If we regard, therefore, the food we consume as the direct source of all this heat and the mechanical energy displayed by the body, it is obvious we can obtain by their measurement a fair idea of the nutritive values of various food-stuffs. The problem is, however, not of a uniformly simple nature. In the case of the water and mineral salts of the food, their nutritive value is not difficult to ascertain because they are simple bodies, and do not undergo any very great chemical change in the body. The nutritive value of the proteins, fats, and carbo-hydrates, however, is not so easy to determine, because not only are they complex bodies in themselves, but, moreover, undergo complicated and ill-understood changes within the body; their nutritive value, therefore, cannot be very accurately expressed.

The simplest measure of the potential energy is the amount of heat which can be obtained by complete combustion of the chemical compounds representing the potential energy. As a standard or measure of heat, we have the *calorie*, which means the amount of heat required to raise the temperature of one gramme of water 1° C. This is the small calorie. For measuring the heat value of foods, it is usual to employ the large or kilo-calorie, which means the amount of heat required to raise one kilogramme (one litre) of water 1° C. or, which is the same thing, one pound of water 4° F. This larger heat unit is written *Calorie*.

Applying this principle, that as heat production is related to the amount of chemical action ensuing so likewise is mechanical power production, we find that as a measure of the utility of food, the value of the various food

principles as mechanical power producers will correspond with their value as heat producers. Those food principles, which by oxidation give rise to the greatest amount of heat, will, of course, theoretically have the greatest capacity for the production of working power; that is, will possess the greatest potential energy. This theoretical potential energy is not only different in the case of each class of food-stuffs, such as protein, fat, and carbo-hydrate, but differs also in different foods of each of these classes. In the case of many food-stuffs, their actual value in respect of capacity for heat production has been determined experimentally, and expressed in relation to the performance of work. The heat-equivalent of the organic substances cannot be exactly computed from the known heat-equivalents of carbon and hydrogen, because of the amount of heat which is set free by the union of the oxygen with the carbon and hydrogen; further, a part is used up in the separation of the hydrogen atoms from the carbon atoms, and of the carbon atoms from each other. This amount of heat may vary greatly in different compounds, because the atoms are more or less firmly combined with each other, and varying amounts of heat are set free by their union. Metameric compounds are known to produce different heat-equivalents.

To overcome these difficulties, the heat-equivalents of foods have been determined by direct calorimetric methods. Taking the above-mentioned estimate of the mechanical equivalent of heat as a basis of calculation, the following table has been constructed. As the figures represent the average caloric value yielded by one gramme of various foods as contained in an ordinary mixed diet, allowing for defective absorption and for excretion of imperfectly oxidised residues they may be taken as indicating the true value to the body of the different nutritive constituents as sources of energy.

Food.	Calories.	Food.	Calories.
Apples (raw)	0·54	Horseflesh	3·90
Arrowroot	3·40	Macaroni	3·47
Bacon	8·86	Mackerel	1·70
Beef (fat)	3·22	Maize	3·71
Beef (lean)	0·98	Milk	0·70
Beer (bottled)	0·81	Oatmeal	4·44
Biscuit	3·82	Oysters	0·45
Bread (ord. white)	3·03	Peas (green)	3·31
Butter	8·60	Potatoes	0·98
Cabbage	0·32	Raisins	3·65
Carrots	0·57	Rice	3·51
Cheese (American)	4·10	Rusks	3·40
,, (Cheddar)	4·36	Sago	3·38
,, (Dutch)	3·10	Salmon	2·23
,, (Stilton)	4·20	Sardines (in oil)	2·95
Duck	1·83	Sugar (brown)	4·10
Eggs (one)	2·85	Tapioca	3·40
Flour (white)	3·50	Tongue (tinned)	3·00
Haddock (raw)	0·80	Turbot	2·00
Halibut	1·30	Veal	0·75
Herring	1·62	Venison	0·76

A table of this kind is useful in showing what can be obtained from our food, but it must not be supposed that the value of food is in exact relation to the possible energy which it can furnish. In order that the energy shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner

proper for nutrition. The mere expression of potential energy cannot fix dietetic value, which may be dependent on conditions in the body unknown to us. Rubner has shown that, after making allowance for incompletely oxidised products, the heat value of one gramme of the chief alimentary principles, when taken into the body, is as follows :—

Protein	4·1 Calories.
Fat	9·3 ,,
Carbo-hydrate	4·1 ,,

If we know what is the percentage composition of any given food in terms of protein, fat and carbo-hydrates, it is quite easy to find the total Calories yielded by 100 parts of the food in question. Where the amount of food is expressed in ounces, the above statements must be multiplied by 28·34 ; in other words, an ounce of protein or carbo-hydrate would yield 116 Calories, while an ounce of fat would yield 263·5 Calories.

With regard to useful work and the amount of energy required to be supplied by food to produce that external work, it is estimated that, under ordinary circumstances, a man transforms one-sixth of the total available energy of his food into work, the rest being lost in the form of heat. This loss is inevitable, but it compares favourably with that experienced in a steam-engine, where the work done is about one-eighth of the potential energy of the fuel consumed. As the average external work of an ordinary man at rest is calculated to be equivalent to some 410 Calories, the total heat value of his food should not be less than six times this, or say 2500 Calories. On this basis the following table (Rubner) may be accepted as standards of the number of Calories which must be supplied for work of different degrees of severity :—

(1) Rest (clerk working in an office)	2500 Calories.
(2) Professional work (doctor or lawyer)	2631 ,,
(3) Moderate muscular work (painter or plumber)	3121 ,,
(4) Severe muscular work (bootmaker)	3659 ,,
(5) Hard labour (navvy or blacksmith)	5213 ,,

QUANTITY OF THE FOOD-STUFFS REQUIRED IN HEALTH.

So far we have discussed the nature, uses and nutritive values of the food-stuffs individually ; their functions are clearly (1) to furnish material for growth and repair of the body tissues, (2) to provide potential energy for expenditure in the form of heat and work. We have now to consider how much food must be supplied daily to carry out these functions efficiently. Few problems are of greater importance to the physical and mental well-being of a race than that of its diet, yet it may be stated at once that to this question no conclusive reply has been furnished by physiology. There is abundant evidence to prove that no one group of the alimentary substances is alone sufficient to sustain life for any length of time, but that a mixed diet is necessary. Such evidence is derived from instinctive proclivities, from considerations of the comparative anatomy of our digestive organs, from experience and experiment. Experience, further, teaches us that our requirements as to food vary with our exposure to different conditions, and that according to the expenditure of our bodies so should the materials be supplied which are best calculated to yield what is wanted. The human body has been compared to a machine, but it differs therefrom in this, that wear is constantly going on independently of any useful work done, which is not the case in a mechanical engine. Determinations as to the quantity of

food daily required by the body have been obtained by means of extended observations of the diets of classes and communities, and also by estimating the sum of excreted matters, which, of course, must be compensated by a suitable supply of food.

Standard Diets.—A vast amount of evidence as to actual or class dietaries has been collected by a variety of workers, notably by Playfair,* Atwater,† Dunlop,‡ Paton § and Rowntree.||

From these sources and as illustrative of a number of class or actual dietaries under a variety of conditions, the following table has been constructed :—

Class.	Nutritive Constitutents.			Potential Energy.
	Protein.	Fat.	Carbo-hydrates.	
	Grammes.	Grammes.	Grammes.	Calories.
English labourer at moderate work	109	68	492	3096
London seamstress (in 1865)	53	33	316	1820
Lancashire weaver, working full time	151	43	622	3569
,, ,, in time of scarcity	60	28	398	2138
London journeyman tailor	130	40	525	3060
English agricultural labourer (summer)	88	63	520	3078
,, ,, ,, (winter)	77	57	466	2750
German mechanic	131	54	479	3085
German painter	87	69	366	2500
American University oarsman	155	177	440	4085
German miner	133	113	634	4195
English blacksmith	176	71	665	4117
French miner	118	80	580	3605
American glass-blower	95	132	481	3590
Swedish workman	135	79	523	3436
Italian brickmaker	167	117	675	4640
English bricklayer, in good work	133	80	520	3424
English miner (Northumberland)	131	74	479	3190
English professional man	100	90	256	2300
German professional man	80	120	240	2428
Scotch labourer	65	62	510	2934
English professional footballer	144	120	475	3654
American artisan	127	186	531	4428
London stockbroker's clerk	78	50	410	2475
London charwoman	60	41	360	2203
Average	111	82	478	3200

Interesting as these figures are, care needs to be taken that their limited range of usefulness is not forgotten. They indicate the needs of typical individuals living under known conditions, but they cannot be applied rigidly in any or every particular case. The facts show strikingly the relation between the muscular activity of the individual and the caloric value of his diet and, on that account, are exactly what is to be expected from the theory of the conservation of energy. The most obvious lesson to be learnt from these actual dietaries appears to be that (1) people doing active muscular work, such as blacksmiths and athletes, when free to choose their diet, select a dietary having a total fuel value of some 4400 Calories; (2) people doing ordinary muscular work, such as carpenters, farmers and labourers, choose a diet representing some 3300 Calories; and (3) people

* Playfair: *On the Food of Man in Relation to his Useful Work,* 1865.
† Atwater: Report of United States Commissioner of Fish and Fisheries, 1888.
‡ Dunlop: Report of the Prison Commissioners for Scotland, 1899.
§ Paton: *A Study of the Diet of the Labouring Classes in Edinburgh,* 1901.
|| Rowntree: *Poverty: a Study of Town Life,* 1903.

doing light muscular work, such as professional men and clerks, select a dietary representing about 2500 Calories.

We may now inquire what light physiological experiment throws on this subject, more particularly what proportion of the whole diet, protein, fat and carbo-hydrate, should each contribute. The metabolic output of an individual varies naturally with his size, age and work, but it may be said that an ordinary man, weighing 70 kilos or 11 stones, excretes 20 grammes of nitrogen and 300 grammes of carbon daily.

Assuming protein to contain 16 per cent. of nitrogen, it is clear that an input of 125 grammes of protein will supply the requisite amount of nitrogen, but we cannot accept this as the absolute answer to the question as to how much protein such a man must consume daily, owing to the fact that the body can establish nitrogen equilibrium on various quantities of protein. In a typical man, 20 grammes input of nitrogen means 20 grammes output, so also 15 grammes input is followed by 15 grammes output, and so on, the nitrogen excretion keeping pace with the nitrogen intake. The question arises, how much is the best ? The answer is not easy, because we do not know how much protein or nitrogen is actually needed to keep the tissues in repair. A starving man will eliminate 4 grammes of nitrogen daily, and, practically, nitrogenous equilibrium cannot be established on less than an intake of 12 grammes. Can we accept this as the minimum ? The view held, hitherto, by physiologists is that we cannot, because, when the protein is reduced to a minimum, there is a risk of having "threadbare tissues" and a consequent lack of disease-resisting power on the part of the body ; moreover, to do so is to ignore the fact that the function of protein is to supply energy as well as merely repair tissues, and that it is unsafe to rely only on the fats and carbohydrates as sources of heat and energy. On this principle it has been held that the proper nitrogen standard for the ordinary man of 70 kilos weight is 118 grammes of protein daily. This represents 105 grammes of absorbable protein or 16 grammes of nitrogen and equivalent to 1·5 grammes of protein per kilogramme of body weight.

Recent work on metabolism has seriously challenged this view. On the one hand, theoretical reasoning from the fact that an excess of nitrogen is so rapidly eliminated from the body and, on the other, practical experiment suggest that protein in this large amount is not necessary in health to supply the needs of the body, but rather increases the work of nitrogenous excretion with no apparent advantage. Folin * suggests that nitrogenous katabolism is of two kinds, one immediate, inconstant, varies with the food and leads to the formation of urea and the inorganic sulphates ; the other is constant, smaller in amount and largely represented by kreatinin, neutral sulphur compounds, some uric acid, aromatic sulphates and possibly a little urea. This latter form of metabolism may be regarded as tissue or *endogenous* metabolism, whilst the other is *exogenous*. The endogenous metabolism marks the limit of the lowest level of nitrogenous equilibrium, and the protein input sufficient to maintain it is the indispensable minimum. It is possible that the protein which is metabolised exogenously is by no means necessary ; there is certainly evidence to show that it can be replaced by non-nitrogenous food. Or, we may say that the organism requires only the small amount of nitrogen necessary for endogenous metabolism, and that yielded by an excess protein input is unnecessary.

Landergren,† Kumawaga ‡ and others have shown that nitrogen equili-

* Folin: *American Journal of Physiol.*, xiii. 1905, pp. 45, 66, and 117.
† Landergren: *Biochemisches Centralblatt*, 1903, vol. i. p. 545.
‡ Kumawaga: *Virchow's Archiv*, 1889, Bd. 116, p. 370.

brium can be maintained at a low level of protein ingestion, such as 15 grammes of protein per day for a time if abundance of carbo-hydrate and fat be taken. Chittenden's * work is more convincing, as he carried out experiments over extended periods of time in order to meet the criticism that the test was too short to admit of accurate conclusions being drawn. In one set of experiments five men were fed for periods of from six to nine months on an average daily metabolism of from 34 to 56 grammes of protein per day. In three of the cases, individuals of different body weight, there was a close agreement in the amount of nitrogen required, which was 0·1, 0·093, and 0·102 gramme respectively per kilogramme of body weight, the other two cases requiring somewhat more, viz., 0·14 and 0·139 gramme of nitrogen per kilogramme of body weight, which is about half of the usual standard. Moreover, in these experiments the non-nitrogenous food was not increased. Further, to meet the criticism that such diets could not be borne indefinitely, one of the subjects had lived at that level for four and a half years, and, as he believes, with great gain to himself. Similar results had been obtained in eleven soldiers from the Hospital Corps of the United States army, also with a third group of men, eight in number, mostly athletes, in whom the nitrogenous intake was reduced to from 0·134 to 0·108 gramme per kilogramme of body weight per day. Chittenden's view is that 0·10 gramme of protein capable of metabolism per kilogramme represents the minimum protein requirement, but it would probably be advisable to adopt a standard somewhat above this figure and to give from 50 to 60 grammes of absorbable protein to a man of from 60 to 70 kilogrammes weight—this is virtually a reduction of 50 per cent. on the generally accepted standard.

It may be asked, what practical conclusions are to be drawn from these divergent statements ? In the first place, we would observe that Chittenden's results must remind every one as much of acquaintances whose consumption of protein is exceedingly small as they do of other people who take excessive amounts of protein and of food generally to the obvious detriment of their health. We question whether the evidence, however, warrants a permanent reduction of the protein intake for an ordinary man to Chittenden's suggested figure of 0·12 gramme of absorbable protein per kilogramme of body weight. When we consider the bearing of protein food upon the performance of muscular effort it is true we find the energy for this work furnished by non-nitrogenous substance ; but, as demonstrated in the analysis of class dietaries, we find that those who habitually perform hard muscular work consume more protein, if it is available. Takaki † has told us how, in the Japanese navy, the health of their seamen has improved by increasing the daily protein value of the ration from 91 grammes to 155. Some instructive facts in this direction are given also by Benedict,‡ who suggestively remarks that the negro and the poor whites of the Southern States of America and the labourer of Southern Italy all live on diets poor in protein, and that their sociological conditions and commercial enterprise are on a par with their diet. It is probable that the orthodox standard of 118 to 125 grammes of protein daily may err on the side of excess for the ordinary man doing no specially hard work ; equally, the newer idea of reducing the amount to half may be open to risk if accepted as a standard for the general population. From the available evidence, we do not think it has been proved that a diet containing protein in a much smaller proportion than

* Chittenden : *Physiological Economy in Nutrition,* 1905.

† Takaki : "On the Preservation of Health amongst the Personnel of the Japanese Navy and Army," *Lancet,* May 19 and 26, 1906.

‡ Benedict : *American Journal of Physiology,* August 1906.

that of 100 grammes a day for an adult of 70 kilogrammes, is permanently beneficial either to the individual or to the race, and especially for those whose occupations require considerable muscular exertion.

We may now pass on to inquire how much fat and carbo-hydrate are required in a daily diet. These two alimentary groups are the main source of the carbon supplied to and needed by the body and also of the energy. For a man of 70 kilogrammes in body weight, doing ordinary work, some 300 grammes of carbon are needed daily to meet the daily loss under this head. If we assume that a man takes in 100 grammes of protein of which only two-thirds is fully metabolised, we get 36 grammes of carbon available from this source, leaving 264 grammes to be supplied by fats or carbo-hydrate. So far as a mere source of energy is concerned, the body cells are indifferent whether it be fat or carbo-hydrate, but we must remember that it takes $2\frac{1}{4}$ parts of the latter to supply as many Calories as one of the former. On the other hand, fat is more slowly metabolised than carbo-hydrate, is more expensive, and usually less digestible. Experience indicates that for economic and digestive reasons, about one-fifth of the balance of carbon should come from fat, in other words, some 60 grammes of fat are desirable, yielding 46 grammes of carbon, the remaining 218 grammes of carbon being obtained from an input of 540 grammes of carbo-hydrate. A dietary prepared on these lines would have a fuel value of 3182 Calories; possibly the fat might need to be reduced, say, to 50 grammes, in which case, unless it were replaced by carbo-hydrate, the fuel value of the dietary would not be more than 3089 Calories. What should be the exact proportion of fat to carbo-hydrate is difficult to say; many authorities have advocated 1 part of fat to 10 of carbo-hydrate, but some direct observations on this point made by Forster * on the actual dietaries of individuals, show the fat obtained to have been considerably greater than the amount fixed in the orthodox standard. In our opinion, the ratio in a well-designed dietary should be 1 part of fat to 7 or 8 of carbo-hydrate, but it is impossible to lay down any hard and fast rule; opportunity, digestion and pecuniary circumstances are the determining factors. "One point in which fat is not able to replace carbo-hydrate in its dynamic equivalent is in protein-sparing power. In this direction 1 part of fat is not as efficient as $2\frac{1}{4}$ parts of carbo-hydrate"; † while starch can diminish protein katabolism 20 per cent., a similar weight of fat will diminish it by 30 to 40 per cent. "If, therefore, the proportion of fat in a diet be increased, the amount of protein consumed must also be increased."

The general principles of diet may be summed up thus :—(1) No single nutritive principle, whether nitrogenous or non-nitrogenous, can support life except for a very short time. (2) Life may be supported upon one nitrogenous and one non-nitrogenous principle for a very long time, but for a permanency salts would require to be added. Thus, proteins and fats, or proteins and starches, would support life. (3) For the best forms of diet, both fats and carbo-hydrates are needed in addition to nitrogenous matter, and in all probability both starch and sugar among them. It would also appear that a due admixture of more than one form of nitrogenous principle is advisable.

The standard amounts of the different nutritive constituents required daily may be stated thus :—

Protein	100 grammes	yielding energy as 3182 Calories.
Fat	60 ,,	
Carbo-hydrate . . .	540 ,,	

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* Forster: *Pettenkofer and Ziemssen's Handbuch der Hygiene*, Bd. i. p. 137.

† Hutchison: *Food and Dietetics*, p. 28. This work should be consulted by all interested in this subject.

Such a standard may be regarded as suitable for a man of average size and weight, doing a moderate amount of muscular work. In the following table are similar standards fixed by other workers :—

Authority.	Protein.	Fat.	Carbo-hydrate.	Calories.
Playfair	119	51	531	3140
Voit	118	56	500	3055
Moleschott	130	40	550	3160
Rubner	127	52	509	3092
Munk.	105	56	500	3022
Atwater	125	125	450	3520
Hutchison	125	50	500	3027
Chittenden	60	30	480	2493
Average . .	113	57	502	3063

Expressed in terms of everyday articles of food, the mean of these dietaries is represented by the following :—Sirloin of beef 10 ounces, two eggs, cheese 1 ounce, butter 2 ounces, bread 12 ounces, potatoes 8 ounces, sugar 1½ ounces, milk 1 pint.

Various conditions of life influence the amount of food required ; the more important of these are work, rest, weight, age, sex and climate. No one disputes the view that with an increase of *muscular work* there must be a corresponding increase in the total amount of food consumed ; the problem is, should it be met by an increase of protein, of fat, or of carbo-hydrate, or should all be increased. As modern research indicates that muscular work makes no special demand on one nutritive constituent more than another, it is logical to assume that all must be increased. The class dietaries already given confirm this, and from an examination of such diets the following standards have been suggested to serve as guides to the amount of each nutritive constituent required during the performance of hard labour :—*

Authority.	Protein.	Fat.	Carbo-hydrate.	Potential Energy.
	Grammes.	Grammes.	Grammes.	Calories.
Playfair	185	71	568	3750
Voit	145	100	450	3370
Rubner	165	70	565	3644
Atwater	150	150	500	4060
Average . .	161	97	520	3706

Mental work appears to influence the amount and nature of the food required in a very different way from muscular work. There is no special brain food, and mental work does not increase appreciably tissue waste. For the brain worker the digestibility of food is of more importance than its chemical composition ; the one essential seems to be that the protein consumed should be animal rather than vegetable. This possibly explains why it is easier for a man doing bodily work to be a vegetarian than for one who is engaged in mental work. *Rest*, as might be expected, demands less food than muscular work ; and in the diet of the passive life the fats and carbo-hydrates should be relatively more restricted than the proteins, because

* The student desirous of going further into this question will derive advantage by consulting the following :—Bulletins Nos. 44, 45, 53, 63, 75, 98, 109, and 117 of the United States Department of Agriculture. These monographs give details of the work of Atwater, Bryant, Benedict, Woods, Carpenter, Rosa, Sherman, and other workers in this field.

16

during rest the excretion of carbon dioxide is more affected than that of nitrogen.

As bearing on the demand for food, the influence of *build* and *age* appear to be of more importance than *weight* and *sex*. Thus, a man whose weight is due mainly to muscle will require relatively more food, especially protein, than one who owes his weight to bone or fat. As affecting the amount of heat required from food, the individual surface area is probably of more importance than mere body mass; from this point of view, for every 11 square feet about 1500 Calories must be supplied; the extent of body surface in an average man is, according to Hutchison, about 21½ square feet. These same factors influence the relative food requirements of the two sexes. Women are usually smaller than men; further, there is some evidence that the tendency of metabolism in the female is towards anabolism, while in the

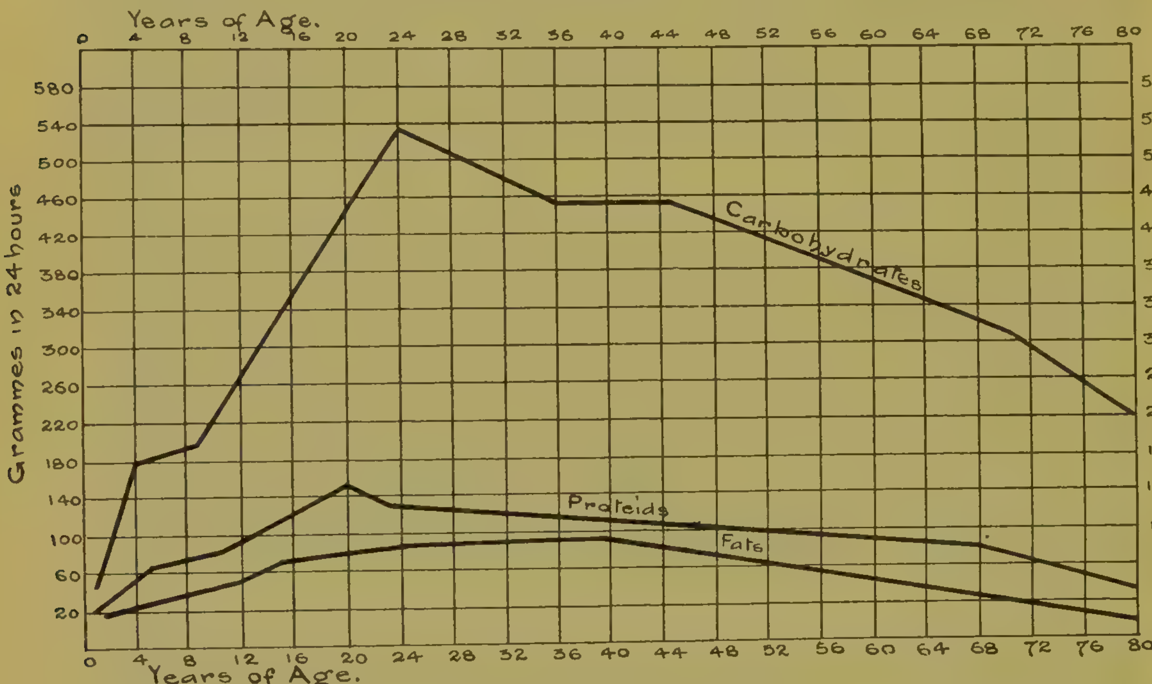


FIG. 27.—AMOUNT OF EACH NUTRITIVE CONSTITUENT REQUIRED AT DIFFERENT AGES. (AFTER HUTCHISON.)

male it is towards katabolism. Upon this supposition it is estimated that, if a man consumes 10 parts of food, a woman under similar conditions should require only 8 parts. In estimating the influence of age upon food requirements, we find that a child, relatively to its weight, requires the greater amount of food; this is because the assimilative powers of a child are greater than those of an adult, and those of the latter greater than those of an old person. In other words, the danger of over-feeding the old is nearly as great as that of under-feeding the young. Hutchison * gives the accompanying graphic representation of the relative needs of protein, fat and carbo-hydrate according to years of age (Fig. 27).

The influence of climate on the amount of food required is probably over-estimated. Too much importance is attached to heat production, by disregarding the fact that man adjusts the temperature of his body to that of the surrounding medium, not by increasing or diminishing the amount of heat he produces from food, but by the regulation of heat lost by means of clothing. In very cold climates, the demand for heat is undoubtedly so great that it can no longer be met by diminishing loss, the deficit being made

* Hutchison, *op. cit.* p. 47.

up by an increase of heat production by a greater consumption of food. This is best done by taking in more fatty food, as this is the most compact form of food fuel we have. Similarly, in very hot climates the demand for heat is so small that it can no longer be adjusted by an increased loss; in this case, we instinctively avoid the proteins or those nutritive constituents from which a large amount of heat can be produced in a short time. For the same reason fats are sparingly consumed, but the proportion of vegetable food-stuffs relatively increased. It is curious to note that the few exact experiments, which have been made on the point, show that to keep the body weight constant as much food must be eaten in summer as in winter; this, being coincident with a lessened desire for food in hot weather, forces the inference that a slight loss in weight is inevitable in circumstances of heat.*

Having, therefore, an established series of dietetic standards and a knowledge of the chief points to which attention must be directed in regard to food, it is important to be able to examine any given diet in the light of these facts, and be able as well to construct a dietary. To do this, however, it is necessary to have some knowledge of the mean composition of the various articles of diet. The table on page 244, constructed from various sources, shows the percentage composition of the more ordinary articles of food.

Calculation of Diets.—Of course the figures given are largely approximate, but are sufficiently accurate for the calculation of any dietary, the mode of doing which is very simple. The quantity of uncooked meat or bread being known, and it being assumed or proved that there is no loss in cooking, a rule of three brings out at once the proportions. Thus, the ration allowance of meat for soldiers being 12 ounces, 2·4 ounces, or 20 per cent., is deducted for bone, as the soldier does not get the best parts. The quantity of protein in the remaining 9·6 ounces will be $\frac{20{\cdot}5 \times 9{\cdot}6}{100} = 1{\cdot}96$, the fats will be 0·8064, and the salts 0·1536 ounce. So again, in the case of eggs, if two eggs be used, each weighing 2 ounces, 10 per cent. must be deducted for shell from the weight of egg. This gives 3·6 ounces as the nett weight of egg available, and taking the composition of eggs to be as given in the table we get, proteins 0·48 ounce, fats 0·41 ounce, and 0·036 ounce of salts from the two eggs.

Whenever practicable, the nutritive value should be calculated on the raw substance, as the analyses of cooked food are more variable. Allowance must then be made for any loss which occurs in cooking; this should not be great, but very often in ordinary domestic cooking this may amount to as much as 30 or 40 per cent.

Although a diet may fulfil theoretical requirements, practical experience soon shows that it must be sufficiently varied. It is the great diversity which exists as regards the food consumed by the human race in all parts of the world that is the most remarkable feature in the study of dietaries. Some people live upon a wholly vegetable, others on a wholly animal, and others on a mixed diet. It has already been explained how unsuited any single vegetable food, such as bread, or any single animal food, such as meat, is to supply the daily requirements of the body, and how a judicious mingling of the various food-stuffs affords the greatest nourishment in the least bulk. The mixed diet may be regarded as that which in Nature's plan is designed for man's sustenance. On this he appears to attain the highest intellectual and physical vigour, and it is this diet which he

* Ranke: *Zeitsch. f. Biologie*, Bd. 40, p. 288; *also see* Hirschfeld: *Deutsche Med. Wochsch.*, 1902, p. 674.

consumes by general inclination when circumstances allow the inclination to guide him; also it is in conformity with the construction of his teeth and

Articles of Food.	In 100 parts.					
	Proteins.	Fats.	Carbo-hydrates.	Salts.	Nitrogen.	Carbon.
Beef, lean	20·0	3·5	—	1·6	3·2	12·62
,, medium	20·5	8·4	—	1·6	3·28	15·37
,, very fat	16·75	19·0	—	3·5	2·68	22·62
Veal, lean	18·88	4·41	—	0·5	3·02	12·74
,, fat	19·20	7·20	—	1·33	3·07	15·00
Mutton, medium	17·11	5·77	—	1·33	2·73	12·87
,, very fat	16·62	25·61	—	1·10	2·65	27·50
Pork, lean	20·25	6·81	—	1·10	3·24	15·43
,, fat	14·54	37·34	—	0·80	2·32	35·27
Bacon, dried	8·80	73·30	—	2·90	1·40	59·40
Ham, smoked	24·00	36·50	—	10·10	3·84	39·37
Meat powder, dried	69·50	5·84	0·42	13·25	11·12	39·08
Horseflesh	21·71	2·60	—	1·10	3·47	12·80
Herring	14·55	9·00	—	1·78	2·32	11·25
Pike	18·42	0·53	—	1·00	2·94	9·60
Carp	21·86	1·00	—	1·33	3·49	11·68
Salt cod	27·00	0·36	—	22·00	4·32	13·77
Canned meat (American)	29·00	11·50	—	3·60	4·64	23·10
Corned beef (Chicago)	23·30	14·00	—	4·00	3·72	22·00
Pemmican	35·40	55·20	—	1·8	5·60	59·10
Poultry	21·00	3·80	—	1·2	3·36	13·35
Ham sausage	12·87	24·43	10·52	3·3	2·05	29·48
Beef sausage	27·31	19·88	15·10	5·5	4·36	35·35
Eggs, hen's	13·50	11·60	—	1·0	2·16	15·45
Milk, cow's	4·20	3·70	4·50	0·7	0·67	6·67
,, goat's	4·29	4·70	4·60	0·76	0·68	7·50
,, condensed, English	12·00	8·40	50·80	2·00	1·92	32·62
,, ,, Swiss, sweetened	12·30	11·00	48·70	2·40	1·96	33·88
,, ,, ,, unsweetened	11·35	11·25	13·35	2·00	1·81	19·44
Cream	2·70	26·70	2·80	1·80	0·43	22·49
Butter, fresh	2·00	85·00	—	1·00	0·32	64·75
,, salt	—	80·00	—	3·00	—	60·00
Margarin	0·75	82·00	—	5·22	0·12	61·87
Cheese, Dutch	28·00	23·00	1·00	7·00	4·48	31·50
,, single Gloster	31·00	28·50	—	4·50	4·96	36·80
,, poor quality	32·00	9·00	7·00	4·00	5·12	25·55
Eels	12·50	28·50	—	1·50	2·00	27·55
Goose	16·00	45·50	—	0·50	2·56	41·90
Bread, average wheaten	8·00	1·50	49·20	1·30	1·28	27·25
Biscuits	10·60	1·30	73·40	1·70	1·70	41·94
Flour, wheat of average quality	11·00	2·00	71·20	0·80	1·76	39·04
Barley meal	12·70	2·00	71·00	3·00	2·03	39·80
Oatmeal	12·60	5·60	63·00	3·00	2·01	38·85
Maize	10·00	6·70	64·50	1·40	1·60	39·03
Macaroni	9·00	0·30	76·80	0·80	1·44	39·87
Arrowroot	0·80	—	83·50	0·30	0·12	38·00
Potatoes	2·00	0·16	21·00	1·00	0·32	10·57
Peas	22·00	2·00	53·00	2·40	3·52	36·35
Rice	5·00	0·80	83·20	0·50	0·80	40·50
Turnips	1·00	0·20	6·80	1·00	0·16	3·37
Parsnips	1·30	0·70	14·50	1·00	0·20	6·96
Carrots	1·00	0·20	10·00	1·00	0·16	4·65
Cabbage	5·00	0·50	7·80	1·20	0·80	6·00
Soja beans	33·40	17·70	29·10	4·10	5·34	41·54
Cocoa powder (Dutch)	19·66	13·61	12·60	3·60	3·13	25·00
Chocolate (French)	6·18	20·00	54·00	2·20	0·98	39·69

the arrangements of his digestive apparatus in general. However, where custom and habit have given certain races a peculiar suitability for a purely

vegetable diet, the arguments in favour of a mixed diet are not sufficiently strong for the reversal of the customs of many ages.

For translating or changing the elements of a diet into terms of food articles, or *vice versâ*, it is important to remember that no mere calculation of the amounts of food-stuffs can properly measure the efficiency of any particular diet, but that other conditions must be considered; the chief of these will be relative to absorbability of food, digestibility of food, and the effects of cooking.

Absorbability of Food.—Much work has been done on this question, and the results show that the constituents of a mixed diet are better absorbed than those of any one article of food when taken by itself. Atwater * gives the following percentages for nutritive constituents absorbed from a mixed diet:—

	Protein.	Fat.	Carbo-hydrate.
Animal foods	98	97	100
Cereals and sugars	85	90	98
Vegetables and fruits	80	90	95
Ordinary mixed diet	92	94·5	98·5

It is desirable that we do not attach undue importance to a high absorption figure. The intestine seems to require a certain amount of ballast, and a food which leaves little or no residuum may lead to intestinal disturbance as much as one which leaves behind a large unabsorbed residue. Then there is the question of personal idiosyncrasy, as well as the fact that the process of absorption demands a greater expenditure of energy in some cases than in others. For example, to absorb the same amount of protein, four times as much energy has to be expended in the case of bread as in that of milk. It is conceivable that in some diets the intestinal labour to secure absorption may be considerable.

Digestibility of Food.—In order that food shall be digested and absorbed, two conditions are necessary:—the food must be in a fit state to be digested, and it must meet, in the alimentary canal, with the chemical and physical conditions which can digest and absorb it.

Fitness for digestibility depends partly on the original nature of the substance, as to hardness and cohesion, or chemical nature, and partly on the manner in which it can be altered by cooking. Tables of degree of digestibility have been formed by several writers, but it must be remembered that these are merely approximate, as it is so difficult to keep the conditions of cooking equal.

Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, roasted and baked potatoes, and fricasseed chicken are the most easily digested substances in the order here given—the rice disappearing from the stomach in 1 hour, and the fricasseed chicken in $2\frac{3}{4}$ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roasted fowls are rather less digestible—roast beef disappearing from the stomach in 3 hours, and roast fowl in 4 hours. Salt beef and pork disappear in $4\frac{1}{4}$ hours. As a rule, animal food is digested sooner than farinaceous, and in proportion to its minuteness of fibre.

The admixture of the different classes of foods aids digestibility; thus fat taken with meat aids the digestion of the meat; some of the accessory

* Atwater: Ninth Annual Report of Storr's Agricultural Experimental Station, 1896, p. 187.

foods probably increase the outpour of saliva, gastric juice, or intestinal secretion. The fat of all food is very completely absorbed, far more so than the proteins. The same is true of all the carbo-hydrates, with the single exception of cellulose. This was held to be totally indigestible until quite recently, when it was proved, by experiments on ruminants, that from 60 to 70 per cent. of woody fibre does disappear from the digestive canal. Though cellulose can scarcely be classed among the food-substances of human beings, it fulfills an important part by acting as a mechanical stimulus of peristaltic action, and from a dietetic point of view its amount is not without interest.

Cooking of Food.—By cooking, food is rendered more pleasing to the eye, agreeable to the palate, and digestible by the stomach. Apart from the power of removing any obnoxious property in a food by killing any parasites or disease germs existing in it, cooking so alters the texture of a food as to render it more easy of mastication and subsequent reduction to a fluid state by the stomach. Thus a piece of meat, before cooking, is tough and stringy, but when cooked the muscular fibres are given a firmness from the coagulation of their albumin, and the connective tissue which binds the muscle fibres together is made into a soft and jelly-like mass; in other words, during the cooking of animal food there is a gradual but not complete coagulation of the protein constituents, a formation of gelatin from the connective tissues, with a partial disintegration of the whole, and a loss of salts. In the same way, cooking makes vegetables and grains softer, loosens their structure, and enables the digestive juices to penetrate into their substance.

Dry heat converts starch into a soluble form and ultimately into dextrin. This change occurs to some extent in the crust of bread and also in the making of toast. Moist heat causes the starch grains to swell and later to rupture their cellulose envelopes; when this occurs the starch is said to be *gelatinised.* Both this and the coagulation of proteins, whether animal or vegetable, takes place considerably below the boiling-point of water. The effect of boiling upon cane-sugar, especially in the presence of acids, is the production of invert sugar or a mixture of dextrose and levulose. The partial conversion of sugar into caramel is one of the means by which flavour is developed in food by cooking. The fats of food are much less affected by heat than the proteins and carbo-hydrates.

Practically there are six common methods of cooking, namely, boiling, stewing, roasting, broiling or grilling, baking and frying; each of these presents some special features.

Boiling.—This may have for its object either the extraction from the food of the nutritive principles or their retention in it. If we wish to extract all the goodness of meat into some surrounding liquid such as water, as when we make a soup or broth, the article should be finely cut up and placed in cold water. After it has soaked for an hour, heat should be applied slowly; if a broth is to be made, the heat, though constantly applied, is not allowed to reach actual boiling for some time, by which procedure much of the albumin of the meat is extracted before the subsequent greater heat has been able to coagulate it, and, all the natural juices having for the most part flowed out, the meat itself is left in a nearly tasteless state, but still not without some nutritive value. In the making of a soup the same procedure is adopted, with this difference, however, that the boiling is kept up somewhat longer, whereby more of the gelatin of the meat is extracted, and the actual meat itself, owing to more complete deprivation of its constituent juices, rendered still more tasteless and less nutritious. Thus

treated, the meat yields its essential principles to the surrounding liquid, which gains in flavour and nutritive properties, the essential difference between the broth and the soup being merely one of degree; that is, how much of the goodness of the meat passes out of it into the surrounding liquid. In the making of a broth some of the meat juices, gelatin and other constituents still remain in the meat, because the albumin is permitted to coagulate before they have all escaped; while in the other case practically nothing remains of the meat but fibrous tissue, all the rest having passed out into the soup. A due appreciation of this difference between a broth and a soup is important, especially the fact that after the making of a broth the meat residue has still considerable nutritive value, whereas after the preparation of a soup the meat residue has none.

If, on the other hand, the object of boiling is not to extract the constituents out of meat, but rather to retain in it all its flavour and nutriment, then it should not be cut up, but left as a large piece, plunged suddenly into hot or nearly boiling water, and quickly brought to the boil. The application of sudden heat in this manner coagulates the albuminous matter on the surface of the meat, closes its pores, and makes an impermeable external coat which stops the escape of the juices from the inner and deeper parts. The actual period of boiling need not and should not last longer than a few minutes; after the coagulation of the external parts, the process of cooking ought to be conducted at a low temperature, not exceeding 170° F. or about 77° C. This is the true cooking-point of meat; if the temperature be over 80° C., the protein matters are not only completely solidified, but become hard and indigestible. Over-heating is, therefore, to be avoided; and the slower the cooking, the better the result. During cooking by boiling, the loss of weight in meat is commonly 20 per cent.

Stewing is commonly regarded as a mere modification of boiling; this is only partially true, because they are essentially opposite processes. The essential object in boiling, say a leg of mutton, is to so raise the temperature of the meat, using water as the medium by which the heat is conveyed, that it shall as nearly as possible retain all its juices. Now, in stewing, this is largely reversed, because the water is used not only as a heat-giver, but also as a solvent for extracting out from the meat more or less of its juices. Much of this extraction of meat juice in stewing is more accurately expressed as an act of diffusion rather than of solution, capable of being best secured at high temperatures than low; but experiment teaches us that albumin, which so largely constitutes the diffusible juice of meat, coagulates and gets hard and tough if long exposed to a heat near the boiling-point of water; hence the need, if stewing is to be properly done, and the meat not rendered so tough, curled and hard as to be more or less uneatable, that the process of stewing should be performed at a temperature of 170° F. or so. This can be readily done if a *bain-marie* or water-bath be used. The ordinary carpenter's glue-pot is a familiar form of water-bath, being simply a vessel immersed in an outer vessel of water. The water in the outer vessel may boil, but that in the inner one never does, because evaporation from the surface keeps its temperature lower than that of the water from which it gets its heat. All well-equipped kitchens have these double vessels, and every ironmonger sells them; but in the absence of such a double saucepan, every housewife can readily improvise one by performing the stewing in an earthenware jar or glass placed within an ordinary saucepan containing water. It is the more general appreciation of the value and use of the water-bath mode of stewing by French men and women that makes their average of cooking so much higher

than that of the ordinary English man or woman. English people are apt to speak with contempt of the stewed beef of the Frenchman, forgetting the fact that he never eats it alone, but always associated with a soup or *potage*, which really contains the juices of the beef; and the two dishes combined constitute identical and quite as nutritious articles of diet as the British joint.

Hashing is the same process as stewing, only that the meat has been previously cooked instead of being fresh.

Before dismissing this subject of stewing, a few remarks upon the making of ordinary beef-tea or beef extracts sold under the names of "extract of meat" and "Bovril" may not be inappropriate, particularly as they afford some points of difference from the juices of an ordinary stew. Beef-tea is made by chopping up lean meat very finely and then macerating it in cold water, and the broth thus obtained is heated in order to alter its raw flavour. During this heating, which should not exceed 170° F., or just sufficient to coagulate the albumin and colouring-matter, a scum rises to the surface; much of this is fat, and is rightly removed, but if the heating is carried too high some of the other nutritious elements coagulate on the surface, and get removed instead of being left behind. If well prepared, beef-tea is a highly nutritive and restorative liquid, with an agreeable, rich, meaty flavour. If badly prepared, by being subjected to prolonged boiling, beef-tea is merely a solution of the non-coagulable saline constituents of meat—namely, bodies known as kreatin, kreatinin, lactic acid, and phosphates. These are all most excellent, but to be regarded as stimulants rather than as nutrients. This explains why in some states of prostration, during illness, when the blood is insufficiently supplied with these flesh juices, the administration of beef-tea, beef extracts, and such-like preparations does much good; but the danger lies in regarding them as foods suitable for the normal sustenance of the body.

Roasting.—Just as stewing may be regarded as the national method of cooking on the Continent, so may roasting be regarded as our national method of flesh cooking. Roast meat is usually thought to be more savoury but less digestible than when either boiled or stewed, while, too, the loss is greater, but the same principle underlies it, namely, the retention of the nutritive juices by the formation of a coagulated layer on the surface. In roasting, the juices of the meat are retained (with the exception of those which escape as gravy on the dish), while in stewing they go more or less completely into the water. In stewing, the heat is communicated to the meat by convection or actual contact; in roasting, the heat is nearly all dry heat radiated to the surface of the joint from the fire. The high temperature rapidly given by radiation to the meat surface forms a thin crust of hardened and half-carbonised albumin; this prevents the evaporation of the meat moisture, sets up a certain amount of pressure inside the joint, resulting in the gradual loosening of the fibres and raising of the deeper parts of the flesh to the cooking temperature of about 170° F. In all roasting processes, to hasten its course and prevent burning of the superficial parts, the joint is *basted* or kept constantly enveloped in a varnish of hot melted fat, which, while assisting in the communication of heat, checks the undue evaporation of the juices, or, in other words, during roasting heat convection is established by the medium of a fat-bath, while in stewing or boiling it is supplied by a water-bath.

The average loss on roasting is from 31 to 35 per cent. in weight.

Broiling or *grilling* is the same in principle as roasting, but the scorching of the surface is greater, owing to the larger surface exposed to heat. *Baking*

is analogous, except that the operation is carried on in a confined spac such as an oven. Owing to the limited space and want of ventilation in the chamber or oven in which baking is carried on, the condensed vapour from the article being cooked and the fatty acids, if it be meat, are prevented from escaping, rendering the food so cooked richer and stronger for the stomach. For these reasons, baked food is unsuitable for the sick and delicate. During baking, a joint of meat will lose from 20 to 30 per cent.

Frying, speaking generally, is a bad way of cooking, as owing to the heat being applied through the medium of fat, the article so cooked is penetrated with oily matter and is often indigestible. In frying, the heat is applied usually much above that of boiling water, as the medium, fat, can be heated much above 212° F. before it boils ; and it is probably largely the difference of temperature to which fish is subjected in the two processes that causes the distinction between a boiled sole or mackerel and a fried one. Over and above this, their difference may be due to the fact that the flavouring juices are retained in the flesh of the fried fish, while more or less of them escape into the water in which they are boiled.

The comparative composition of meats, before and after cooking, is shown in the following table.*

	Protein, per cent.	Fat, per cent.	Extractive matter, per cent.	Salts, per cent.
Beef before cooking . .	77·31	15·47	2·98	4·24
„ after boiling . .	79·06	17·38	0·90	2·66
„ after roasting . .	76·73	18·41	1·59	3·27
Veal before cooking . .	71·17	22·45	2·32	4·06
„ after roasting . .	68·36	28·18	0·09	3·37

DISEASES CONNECTED WITH FOOD.

The diseases connected with food form, probably, the most numerous order which proceeds from a single class of causes ; and so important are they, that a review of them is equivalent to a discussion on diseases of nutrition generally. It is, of course, impossible to do more here than outline so large a topic.

Diseases may be produced by alterations in quantity ; by imperfect conditions of digestibility ; and by special characters of quality.

Excess of Food.—In some cases, food is taken in such excess that it is not absorbed ; it may then undergo chemical changes in the alimentary canal, and at last putrefy. Dyspepsia, constipation, and irritation, causing diarrhœa which does not always empty the bowels, are produced ; sometimes the process of absorption goes on too rapidly for assimiliation, in these cases the surplus products of digestion are eliminated by the kidneys. Familiar instances are transient albuminuria following an excessive input of protein, or temporary appearance of sugar in the urine after an extravagant consumption of carbo-hydrates. The general results of habitual overfeeding are more insidious. If it be an excess of fat or carbo-hydrate, the surplus is stored up in the form of fat. In the case of protein, such storage is unusual except in the young. The usual fate of any excess of protein is that it is split up into a carbon moiety which is converted into and stored as fat, and a nitrogen-containing part which results in cleavage products of

* *See* Bulletin No. 21, United States Department of Agriculture, p. 87.

a more or less toxic nature which are possibly concerned in the production of such conditions as gout and rheumatism. These nitrogen compounds have received some notice of late years, and, being constructed on the base C_5N_4, are not infrequently referred to as purins. They exist largely in certain protein foods, such as meat, meat extracts, and glandular organs, such as the pancreas, liver, sweetbread and thymus. They occur in smaller amounts in many vegetables and in certain other articles of diet, notably beer. The chief purin-free foods are milk, cheese, macaroni, white bread, potato, apple, banana, raisin, date and nuts. An excess of food rich in purins is associated undoubtedly with the causation of gout and allied conditions. In this connection, it must be remembered, too, that an excess of protein-sparers may produce very similar results to an excess of protein itself by shielding the latter from complete and rapid oxidation.

Deficiency of Food.—The long catalogue of effects produced by famine is but too well known, and it is unnecessary to repeat it here. But the effects produced by deficiency in any one of the four great classes of aliments, the other classes being in normal amount, have not yet been perfectly studied.

The complete deprivation of proteins, without lessening of the other classes, produces marked effects only after some days. In a strong man kept only on fat and starch, Parkes found full vigour preserved for five days ; in a man in whom the amount of nitrogen was reduced one-half, full vigour was retained for seven days. If the abstention be prolonged, however, there is eventually great loss of muscular strength, often mental debility, some feverish and dyspeptic symptoms. Then follow anæmia and great prostration. The elimination of nitrogen in the form of urea greatly lessens, though it never ceases, while the uric acid diminishes in a less degree. If starch be largely supplied, the weight of the body does not lessen for seven or eight days.

If the deprivation of proteins be less complete the body gradually lessens in activity, and passes into more or less of an adynamic condition, which predisposes to the attacks of all the specific diseases (especially of tuberculosis, typhus and of pneumonia).

The deprivation of starches can be borne for a long time if fat be given, but if both fat and starch be excluded, though proteins be supplied, illness is produced in a few days.

The deprivation of fat does not appear to be well borne, even if starches be given ; but the exact effects are not known. The great remedial effects produced by giving fat in many of the diseases of obscure malnutrition prove that the partial deprivation of fat is both more common and more serious than is supposed. In all the diets ordered for soldiers, prisoners, &c., the fat is greatly deficient in every country. The deprivation of the salts is also evidently attended with marked results which are worthy of more attention than they have yet received.

Scurvy.—Closely connected with the subject of food and dietetics is the peculiar state of malnutrition called scurvy. This is now known not to be the consequence of general starvation, though it is doubtless greatly aided by it. Men have been fed with an amount of nitrogenous and fatty food sufficient not only to keep them in condition, but to cause them to gain weight, and yet have developed scurvy. The starches also have been given in quite sufficient amount without preventing it. The weight of evidence suggests that it is to the absence of some of the salts in food that we must look for the cause. For these reasons, the theory and practice of preventing scurvy has, for many years, followed the lines of including in the dietary fresh

vegetables and fruits, for the sake of the organic acids and salts which they contain. The success following the routine administration of lime-juice, to those unable to obtain fresh fuits and vegetables, has emphasised the correctness of this view regarding the causation of scurvy, but more recent experiences throw doubt upon the idea whether the etiology of the disease is dependent absolutely on a lack of vegetable food. It is well known that many outbreaks of scurvy have occurred among expeditions which were well equipped with vegetable food.

The chief exponents of the view that neither lime-juice nor fresh vegetables prevent scurvy or cure it, and that it is not the absence of these which is the cause of the disease, are Torup of Christiania and Jackson and V. Harley of this country. They maintain that scurvy is due essentially to poisoning by the ptomaines of tainted animal food,* and adduce experimental evidence that such is the case. We confess to being unable to admit that this view has been proved to be correct, though some of the facts are suggestive. We know from experience that many cases are returned as scorbutic which are really cases of simple gingivitis and ulcerative stomatitis due to septic infection of the mouth, following ingestion of dirty or decomposed food. There is nothing in Jackson's and Harley's experiments on monkeys, fed with tainted food, to preclude the possibility of this having taken place, with the result that the anæmia and other so-called scorbutic symptoms were due to intestinal sepsis, much as Hunter explains the etiology of pernicious anæmia.†

The essential feature in the pathology of scurvy is a profound change in the blood in the direction of a lessened alkalinity, due to the deficiency in the food of the neutral salts of the organic acids. Sir A. E. Wright ‡ has pointed out that in most scorbutic dietaries the food-stuffs which are excluded are those, such as green vegetables, tubers and fruits, which contain an excess of bases over mineral acids, while the food-stuffs (meat and cereals) which remain contain a large excess of acids over bases. In view of this consideration, it would seem probable that scurvy is a condition of acid intoxication and, certainly, the idea is supported by the fact that the scorbutic condition is remedied or alleviated by the addition to a diet of any one of a whole series of different substances, such as tubers, green vegetables, fruits, raw blood and fresh meat; these are substances apparently having in common only the circumstance that they all contain an excess of bases over mineral acids. It must be confessed that there are still gaps to be filled up in our knowledge of scurvy, and the incidence of all outbreaks cannot be explained satisfactorily by the theory of a lack of fresh vegetables and fruit or by the action of ptomaines from tainted meat. An analysis of all the evidence, coupled with our own experience, warrants the view that the dominant factor associated invariably with outbreaks of scurvy is the prolonged consumption of preserved food, both animal and vegetable. Such food undergoes in the course of prolonged keeping autolytic changes of a fermentative or analogous nature, in consequence of which the neutral organic salts are changed and possibly toxic products formed; and it is the ingestion of these substances which affects the alkalinity of the blood. These deleterious bodies are not due to putrefactive or bacterial decomposition, nor do they reveal themselves by any change obvious to naked-eye inspection. They may be well summed up in the term "devitalised food"; this devitalisation

* Jackson and V. Harley: *see* the *Lancet*, April 28, 1900, p. 1184.

† Hunter: "*On the Etiology of Pernicious Anæmia*," *Lancet*, 1900, vol. i. pp. 221, 296 and 371.

‡ A. E. Wright: "*On the Pathology of Scurvy*," Army Medical Report for 1895; also *Lancet*, August 25, 1900, p. 565.

or material departure from the fresh condition may be the result equally of faulty preservation, caused by exposure to undue heat, as of prolonged keeping; in other words, the more the constituents of a dietary depart from the fresh condition, and the more prolonged the period over which the consumption of such devitalised food extends, the greater are the probabilities of a development of scorbutic symptoms among the consumers.*

MEAT.

The meats ordinarily consumed are all derived from vegetable feeders, with one exception, namely, pork or the flesh of the pig. Meat is one of the few articles of diet on which life can be supported alone for any length of time. It cannot, however, be regarded as constituting a perfect food; it is relatively much too rich in protein and too poor in other nutritive elements. The relative nutritive value of different meats depends chiefly on the amount of fat they contain, which replaces part of the water and not the protein of the leaner meats. The chief mineral substances found in meat-juice are phosphoric acid and potash, together with certain soluble matters known as extractives. The exact chemical nature of the extractives is still largely unknown, but they appear to have no nutritive value, and are of importance chiefly as the cause of the characteristic taste of meat. The chemical composition of meat varies, depending much on the part or "cut," as well as upon the breed of the animal and the degree to which it has been fattened. About 15 per cent. of ordinary butcher's meat is made up of bone, gristle, tendon and other parts which are inedible. The percentage composition of some common meats is given below.

	Water.	Protein and Gelatin.	Fat.	Ash.
Beef (medium fat) . .	76·5	20·7	1·5	1·3
Mutton (medium fat) . .	65·2	14·5	19·5	0·8
,, (lean) . . .	75·0	18·0	5·7	1·3
Lamb (medium fat) . .	63·9	18·5	16·5	1·1
Veal	71·0	17·0	11·0	1·0
Venison	75·7	19·7	1·9	1·1
Pork (medium fat) . .	60·9	12·3	26·2	0·6
Bacon	22·3	8·1	65·2	4·4
Hare	74·0	22·3	1·1	1·1
Rabbit	66·8	21·4	9·7	1·1

Inspection of Animals.—Animals should be inspected twenty-four hours before being killed. In this country killing is done twenty-four or forty-eight hours before the meat is issued; in the tropics only ten or twelve hours previously.

Animals should be well grown, well nourished, and neither too young nor too old. The flesh of young animals is less rich in salts, fat, and syntonin, and also loses much weight in cooking.

Weight.—An ox should weigh not less than 600 lb., and will range from this to 1200 lb. A cow may weigh a few pounds less; a good fat cow will weigh from 700 to 740 lb. A heifer should weigh 350 to 500 lb.

There are several methods of determining the weight of a live animal;

* In connection with this subject the reader should consult a paper by Ekelöf, on "Med. Aspects of Swedish Antarctic Expeditions, 1901 to 1904," in the *Journal of Hygiene*, October 1904; *also* a paper by Holst and Frölich on "The Etiology of Scurvy," in *Trans. Epidem. Society, Lond.*, vol. xxvi., 1906–7.

the one most commonly used in this country is to measure the length of the trunk from just in front of the scapulæ to the root of the tail, and the girth or circumference just behind the scapulæ; call these L and G respectively, expressing them in feet, then $\frac{2}{3}(5L \times G^2)$ gives the weight in pounds. Add $\frac{1}{20}$th for very fat animals, deduct $\frac{1}{20}$th for very thin ones.

The animal is divided into carcass and offal; the former includes the whole of the skeleton (except the head and feet), with the muscles, membranes, vessels and fat, and the kidneys and fat surrounding them. The offal includes the head, feet, skin, and all internal organs except the kidneys. An ox or cow gives about 60 per cent. of meat, exclusive of the head, feet, liver, lungs and spleen, &c. The skin is $\frac{1}{18}$th of the weight; the tallow $\frac{1}{12}$th. In very fat cattle the weight may be 5 per cent. more, and in very lean cattle 5 per cent. less than the actual weights found by this rule.

A full-grown sheep will weigh from 60 to 90 lb., but the difference in different breeds is very great. It also yields about 60 per cent. of available food. For military purposes the best sheep are those between 60 and 70 lb. in weight; if they weigh over 80 lb. or are excessively fat they should not be accepted unless the contractor consents to remove all superfluous fat. The carcass of good, well-fed mutton should be mackerel-backed, that is, there should be alternate red and white bars over the loins. The average weight of a sheep in India is from 30 to 40 lb.

A full-grown pig weighs from 100 to 180 lb. or more, and yields about 75 to 80 per cent. of available food.

Age.—The age of the ox should be from two to eight years, and a heifer or cow not under two or more than four years old; the age is told chiefly by the teeth, and less perfectly by the horns. The temporary teeth are in part through at birth, and all the incisors are through in twenty days; the first, second, and third pairs of temporary molars are through in thirty days; the teeth are grown large enough to touch each other by the sixth month; they gradually wear and fall out in eighteen months; the fourth permanent molars are through at the fourth month; the fifth at the fifteenth; the sixth at two years. The temporary teeth begin to fall out at twenty-one months, and are entirely replaced by the thirty-ninth to the forty-fifth month; the order being—central pair of incisors gone at twenty-one months; second pair of incisors at twenty-seven months; first and second temporary molars at thirty months; third temporary molars at thirty months to three years; third and fourth temporary incisors at thirty-three months to three years. The development is quite complete at from five to six years. At that time the border of the incisors has been worn away a little below the level of the grinders. At six years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surfaces of the teeth begin to bear a square mark surrounded with a white line; and this is pronounced on all the teeth by the twelfth year; between the twelfth and fourteenth year this mark takes a round form.

The rings on the horns are less useful as guides. At ten or twelve months the first ring appears; at twenty months to two years, the second; at thirty to thirty-six months, the third ring; at forty to forty-six months, the fourth ring; at fifty-four to sixty months, the fifth ring, and so on. But at the fifth year the first three rings are indistinguishable, and at the eighth year all the rings. Besides, the dealers file the horns.

In the sheep, the temporary teeth begin to appear in the first week, and fill the mouth at three months; they are gradually worn and fall out at about

fifteen or eighteen months. The fourth permanent grinders appear at three months, and the fifth pair at twenty to twenty-seven months. A common rule is "two broad teeth every year." The wear of the teeth begins to be marked at about six years. Sheep fit for slaughter should always have a clean, even set of teeth. In the army, those with broken teeth are rejected.

The age of the pig is known up to three years by the teeth; after that there is no certainty. The temporary teeth are complete in three or four months; about the sixth month the premolars, between the tusks and the first pair of molars, appear; in six or ten months the tusks and posterior incisors are replaced; in twelve months to two years the other incisors; the four permanent molars appear at six months; the fifth pair at ten months; and the sixth and last molars at eighteen months.

Condition and Health.—The condition of live cattle is generally told by the handling points, of which as many as twelve are given, but only five need be mentioned, as an animal which is good in these five points is sure to be good in the rest. They are the natches, or the bones by the side of the tail, the twist, the flank, the cod or udder, and the rib. The flesh on all these handling points should feel compact and firm, the twist or parts between the two buttocks should stand prominently out, the flank should appear to meet your hand and drop into it as you handle the animal, the rib should be well covered with compact flesh and the cod or udder should be a large lump of firm fat. In half-fed animals the flesh will not be so firm to the touch as in fully fed ones; the meat of such half-fed cattle wastes very considerably in the cooking, owing to the cells of the adipose tissue being filled with imperfectly formed fat. To be able to tell the condition of a beast by handling requires some practice.

As showing health, we should look to the general ease of movements; the quick bright eye; the nasal mucous membrane red, moist and healthy looking; the tongue not hanging; the respiration regular, easy; the expired air without odour; the circulation tranquil; the excreta natural in appearance.

When sick, the coat is rough or standing; the nostrils dry and covered with foam; the eyes heavy; the tongue protruded; the respiration difficult; movements slow and difficult; there may be diarrhœa; or scanty or bloody urine, &c. In milch cows which are sick the teats are frequently hot.

Diseases of Animals used for Food.—The diseases of cattle which the inspecting officer should watch for are:—

Pleuro-pneumonia.—The commencement of the attack is very insidious; it is not easily recognised at first. The temperature soon rises to 104° or 105° F. and the animal refuses food; a short dry cough develops and the breathing becomes laboured and painful.

Foot-and-Mouth Disease.—At once recognised by the examination of the mouth, feet, and teats.

Cattle Plague.—Recognised by the early prostration, hanging of head, drooping of ears, shivering, running from eyes, nose, and mouth, peculiar condition of tongue and lips, cessation of rumination, and then by abdominal pain, scouring, &c.

Anthrax.—This either appears as a general, or as a localised affection; in the former case it is called apoplectic anthrax, splenic fever, or anthrax fever; in the latter, anthracoid erysipelas or carbuncular fever. If boils and carbuncles form, they are at once recognised; if there is erysipelas, it is called black quarter, quarter ill, or blackleg, and is easily seen. The specific organism may be detected in the blood. The affected animal is often lame, looks dull and apathetic, ceases to feed, shows evidence of

thirst and fever, breathes hurriedly, and appears to be tender to the touch.

Tuberculosis.—Sometimes acute, more often chronic; at first dulness and indifference, increased sensibility, especially of back-muscles and chest-walls, but no emaciation and no diminution of production of milk; later, emaciation comes on, loss of appetite, shortness of breath, and cough; these symptoms become intensified, with hectic.

Actinomycosis.—Caused by the so-called "ray-fungus"; this attacks by preference the lower jaw and tongue, also the lungs and bones, giving rise to tumours which lead to general malnutrition, and occasional death.

Joint-ill, which may be either acute rheumatism or septic arthritis. The latter is not uncommon in young animals, the result of blood-poisoning following on omphalo-phlebitis. In life, animals affected with joint-ill are noticeable by their lameness or inability to rise.

A great number of other diseases attack cattle, which it is not necessary to enumerate. All the above are tolerably easily recognised. The presence of various parasitic diseases cannot readily be detected before death.

The diseases of sheep are similar to those of cattle; they suffer also in certain cases from splenic apoplexy or "braxy," which is considered to be a kind of anthrax, and is said to kill 50 per cent. of all young sheep that die in Scotland; the animals have a "peculiar look, staggering gait, bloodshot eyes, rapid breathing, full and frequent pulse, scanty secretions, and great heat of the body." The disease is induced by a specific bacillus closely allied to that of malignant œdema and black quarter. The disease is spread by the fouling of the ground from the carcasses and excreta of infected animals.

Small-pox in sheep is easily known by the high fever, especially during the pustular stage, by the shedding of wool and flea-bitten appearance of the skin in the early stage, and by the rapid appearance of nodules or papulæ and vesicles. The eruption is often to be seen in the mouth.

The sheep is also subject to black quarter; one limb is affected, and the limp of the animal, the fever, and the rapid swelling of the limb are sufficient diagnostic marks.

The sheep, of course, may suffer from acute lung affection, scouring, red water (hæmaturia), and many other diseases. Of the chronic lung affections, one of the most important is the so-called "phthisis," which is produced by the ova of *Strongylus filaria*. This entozoon has not yet been found in the muscles, and the meat is said to be good. The rot in sheep (fluke disease) is caused by the presence of *Distoma hepaticum* in large numbers in the liver, and sometimes by other parasites. The principal symptoms are dulness, sluggishness, followed by rapid wasting and pallor of the mucous membrane, diarrhœa, yellowness of the eyes, falling of the wool, and dropsical swellings. The animal is supposed to take in *Cercaria* (the embryotic stage of *distoma*) from the herbage. The so-called "gid," "sturdy," or "turnsick," is caused by the development of *Cœnurus cerebralis* in the brain.

The pig is also attacked by anthrax in different forms, by muco-enteritis, and by hog cholera. The swelling in the first case, and the severe fever, accompanied with fœtid diarrhœa and prostration in the second, are sufficient diagnostic marks. It has no apparent relation whatever to enteric fever in man. The condition of the flesh is similar to that produced by septic disease, and it is totally unfit for human food.

The so-called measles of the pig is caused by the presence in the muscular connective tissue of *Cysticercus cellulosæ*. During life there are few indications of the existence of this worm in the animal; the only positive sign to

be obtained is in the mouth, where it may be detected on the inferior and lateral aspect of either side of the tongue, or between this and the lower jaw. The body of the animal has a bloated appearance, and a soft flabby feel; and on firm pressure a crackling sensation may be imparted to the fingers.

Trichina spiralis has its habitat also in swine; it is not confined to the muscle alone, but has been demonstrated in the fat of the body of the pig in large numbers. Animals fed on such fat did not, as a rule, become trichinised. Its presence is indetectable before death, unless found in the muscles under the tongue.

Inspection of Meat.—Meat should be inspected, in temperate climates, twenty-four hours after being killed; in the tropics, earlier.

The following points must be attended to :—

(*a*) *Quantity of Bone.*—In lean animals the bone is relatively in too great proportion; taking the whole meat, 17 to 20 per cent. may be allowed.

(*b*) *Quantity and Character of the Fat.*—The amount of fat varies with the feeding of the animals. In a fat ox it constitutes about one-third of the flesh, in a fattened pig one-half. In beef surplus fat is the excessive fat at the kidneys, pelvic cavity, cod fat, and udder. In mutton that on the back and in the region of the kidneys. In thin or badly fed animals the fat may be as low as 1 per cent. of the meat. The fat usually solidifies after death, and in beef consists chiefly of palmitates, in bacon oleates, in mutton stearates, these respective kinds of fats being soft and fusible in the order named. The colour varies from white to straw-colour and yellow, being whiter in young bulls than in bullocks and cows. The kind of feeding has an effect on the colour of the fat; some oil-cakes give a marked yellow colour. The fat of the horse is always of a yellow colour, and softer; it has a rather unpleasant sickly taste.

(*c*) *Condition of the Flesh.*—The muscles should be firm, and yet elastic; not tough; the pale moist muscle marks the young animal, the dark-coloured the old one; the muscular fasciculi are larger and coarser in bulls than oxen. A deep purple tint is said to indicate that the animal has not been slaughtered, but has died with the blood in it. When good meat is placed on a white plate a little reddish juice frequently flows out after some hours. It should be tolerably dry after being exposed for a short time to the atmosphere; it should possess a pleasant sweet flavour, and when heated should give a savoury odour. Good meat has a marbled appearance from the ramifications of little veins of fat among the muscles. There should be no lividity on cutting across some of the muscles; the interior of the muscle should be of the same character, or a little paler; there should be no softening, mucilaginous-like fluid, or pus, in the intermuscular cellular tissue. This is an important point, which should be closely looked to. In commencing putrefaction the intermuscular tissue becomes soft, and tears easily when stretched.

The chief indications of disease are as follows :—

If there is any adhesion on the chest cavity, it indicates some form of lung disease; if the adhesion is reddish in appearance, inflammation of the lungs may be suspected, and if this be only slight the meat need not necessarily be rejected; if the growth is of a greyish or yellowish appearance, and in masses or nodules, it indicates tuberculosis, and the meat should be rejected. In some cases where the growth is slight a doubt may arise as to whether it is tubercular or not. An examination of the breast gland—situated between the fourth and fifth rib—will enable an opinion to be formed. The gland should be cut in half, and if it be found to contain

small white nodules the animal is tuberculous; if, however, the gland is of a pale brown colour throughout, the animal is healthy. The pleura is often stripped to disguise evidences of tuberculosis; stripped carcasses should be rejected. In the hind quarter adhesions on the peritoneum are a sign of a disease. Tuberculosis, unless in a very advanced stage, is not usually apparent in the hind quarter. In cases of suspected tuberculosis all the glands should be carefully examined, especially those lying close to the vertebræ. All glands should be free from congestion, inflammation, caseation, or calcification. If the animal has been choked or drowned, the flesh is pallid, flabby to the touch, and has a parboiled appearance. If cattle have been over-driven shortly before being slaughtered, the flesh will have a fiery red appearance, and will be moist and wanting in firmness. "Ship fever," which is caused by an animal being knocked about during a voyage, is indicated by the gamboge colour of the outside of the carcass and the discoloration throughout the fat. The flesh of cows slaughtered whilst suffering from milk fever is dark in colour and sticky to the touch.

The degree of freshness of meat in commencing putrefaction is judged of by the colour, which becomes paler; by the odour, which becomes at an early stage different from the not unpleasant odour of fresh meat; and by the consistence. Afterwards the signs are marked, the odour is disagreeable, and the colour begins to turn greenish. In diseased meat there is a disagreeable odour, sometimes a smell of physic; very evident when the meat is chopped up and drenched with warm water. It is a good plan to push a clean knife into the flesh up to its hilt. In good meat the resistance is uniform; in putrefying meat some parts are softer than others. The smell of the knife is also a good test. When testing the sweetness of a hind quarter, it is a good plan to thrust a wooden skewer into the flesh just above "the os pubis," a part known as the facing of the buttock; a fore quarter may be tested by probing above the second or "chuck" rib. The skewer, when withdrawn, should smell sweet. *Cysticerci* and *Trichinæ* should be looked for.

(*d*) *Condition of the Marrow.*—In temperate climates the marrow of the hind legs is solid twenty-four hours after killing; it is of a light rosy red. If it is soft, brownish, or with black points, the animal has been sick, or putrefaction is commencing. The marrow of the forelegs is more diffluent; something like honey—of a light rosy red colour.

Age.—In the young animal the bones are small, soft, porous, and of a pinkish colour, but as the animal grows older the bones become large, harder, less porous, and whiter in colour. The inside part of the ribs is very pink in young animals, but as age increases the pinkness fades away and the ribs at about six or seven years old become quite white. The tips of the spinous processes forming the chine are in the young animal composed of gristle, but ossify about the age of six years. The pubes or aitch-bone is only joined by gristle in the young animal, but this ossifies also about the age of six years. Before this gristle has ossified, the butcher divides it with his knife in dressing the animal and the blue cartilage is plainly seen in the side or quarter afterwards, but after it has ossified the saw has to be resorted to. In an old cow which has had several calves the aitch-bone is very thin and very hard, and the pelvic cavity is large. If the head is left attached to the carcass the age can be told with great certainty by the teeth.

Distinctions of Sex.—In the hind quarter of ox beef is situated, at the root of the pizzle, the erector muscle, which is about 3 inches in length by

1½ inch in breadth. In the bull this muscle is much more fully developed than in the ox, being much wider, darker in colour and coarser in grain. The pizzle in the ox is small and undeveloped, not thicker than the finger, but in the bull it is largely developed; it is often split and partly removed in order to make it appear of the same size as that of the ox, or entirely removed, and the retractor muscle left in. There is more cod fat in ox than in bull beef, and in the bull the cavity is generally seen from which the testicle has been removed.

In bull meat generally, owing to the superior muscular development of that animal, the proportion of muscular tissue or lean meat is much greater than it is in the ox. In the bull the fat is not "marbled" through the lean as is the case with well-fed oxen. This gives the whole quarter of bull a darker and redder appearance than that of the ox. The lean of the young ox is juicy, smooth, and silky to the touch, florid in colour and marbled with fat; but in the bull it is coarse and stringy in texture, harsh to the touch and the marbling absent. The bony structure, and especially the aitch-bone, is very much more massive in the bull than in the ox.

The chief distinguishing features of a fore quarter of an ox from that of a bull is the collar or crest, which in the bull is very large and muscular, requiring at least the whole hand to grasp it, but in the ox is very much smaller, and can be grasped between the forefinger and thumb. In the ox there is a plentiful coating of fat on the exterior coming right to the point of the shoulder, but in the bull the exterior coating of fat is almost entirely absent, the lean being directly covered by the outer skin. In the bull the brisket is coarser, harder, and darker than in the ox.

The quarters of bull stags present very much the same characteristics as those of bulls, but in a somewhat less degree. A bull stag is an animal which has been castrated too late in life, or has had one testicle or a part of one left in.

A cow which has had no calf is called a heifer, but the term heifer by itself is often applied to a young cow that has not had more than one calf.

The principal means of distinguishing cow from heifer beef is the udder. In the heifer the udder is but slightly developed; it is in fact enveloped in fatty tissue, and forms a uniform thick wall on either side of the flank. When a cow has had one calf, the surface of the udder will be slightly soft, but the main portion will still consist of solid fat, and the small ducts through which the milk has come will be just visible. After the second calf the udder will be composed partly of a tough, brown, spongy substance, and partly of fine fat, and the ducts through which the milk has come will be very much larger. As the number of calves the cow has had increases, the udder becomes looser, browner, and more spongy in appearance. To make the hind quarter of a cow resemble that of a heifer, the udder is cut out while the carcass is warm and the skin cleverly fixed over the excised part.

If is very difficult to tell the fore quarter of a heifer from that of an ox. In the fore quarter of a cow the chief indications that the animal is old are the bleached ribs, want of fat on the ribs, a very prominent scapula or shoulder-bone, with a hollowness or falling away on either side of it. The flesh of the heifer is generally silky and juicy to the touch. In the old cow it is generally coarse, dry, and stringy. There is a want of marbling of fat, and the fat streaks are poor or absent altogether.

The differences of sex in sheep can be told in much the same way as in cattle. The ram in relation to the wether presents very much the same appearances as the bull does to the ox. The ram has a thick neck, a generally muscular and massive appearance, and a pizzle twice as thick

as an ordinary lead pencil. The wether has a thin neck and a pizzle about the size of a lead pencil. In old ewes the surface of the kidney fat and also the back will be much veined; the knuckle cartilages, instead of showing the pinkish blue colour of young animals, will be quite bleached, and the udder large and spongy, the holes through which the milk has come being visible.

Immature veal and lamb can be recognised by the pallor of the flesh, softness of the tissue, and excess of moisture. Lamb and veal are often "blown" to produce an attractive appearance. The loose cellular tissue is inflated with air by means of a blow-pipe, and the part smeared with soft fat.

Horse-flesh.—This can be detected by the horse having eighteen pairs of ribs, while the ox has only thirteen pairs; the tongue of the horse is smooth at tip and base of blade, and the ox's tongue is rough; the colour of the flesh of the horse is much darker and coarser in fibre than that of the ox; and the bones are heavier than the ox; the whole of the fat of the horse is oily, yellow, has a disagreeable flavour, and is separated from the lean. The odour of the meat is different from that of beef.

The viscera if seen are characteristic. The apex of the heart of a horse is rounded, while that of an ox is pointed. There is no os cordis in the horse. The liver of the horse has three distinct lobes and a small supernumerary lobule; there is no gall-bladder. In the ox and sheep, the liver is not divided into lobes, at most only a small lobe at the upper and hinder border, and there is a gall-bladder. The kidneys in the ox are lobulated, but not so in the horse.

Goat-flesh.—The flesh of an old goat is dark, harsh, and strong with a peculiar goaty smell; the shanks of the fore and hind legs are very thin, ribs white, outer coating of carcass deep red, neck very thin in nanny-goat and very thick in the he-goat.

Sausages.—Decomposing sausages are difficult of detection until the smell of putrefaction appears. Artmann recommends mixing the sausage with an excess of water, boiling and adding freshly prepared lime-water. Good sausages give only a faint, not unpleasant, ammoniacal smell; bad sausages give a very offensive, peculiar ammoniacal odour.

Refrigerated or Chilled Meat.—This is largely imported from North and South America. In preparing refrigerated meat the animals are carefully slaughtered, and the carcasses allowed to cool naturally; then after being quartered they are placed in a cool chamber in which the temperature is gradually reduced to a point below freezing. They are then placed on board vessels fitted with refrigerating chambers. It is, generally speaking, excellent meat, the produce of very good, well-fed cattle. Refrigerated meat is allowed by contract in the army, except during the months of August and September, but the proportion of refrigerated beef and frozen mutton must not exceed 60 per cent. of the total weekly issue.

Refrigerated meat can be distinguished by:—

1. The bruised condition of the shanks, owing to the chain which is passed round the hind legs during the process of slaughtering. This method has now been so much improved that defacement in this manner is often scarcely noticeable.

2. The fat of the meat is pink, owing to its being stained by the juice of the lean meat which escapes.

3. The outside of the meat will present a *dead* colour, when compared with the lustre seen on the outside of good fresh meat.

4. The dressing is not always so clean and neat as in English dressed

meat, and the pizzle and root are always entirely removed. The vertebræ are sawn instead of chopped through; the hind quarter usually contains three ribs instead of one, the fore quarter being shortened proportionately.

On removing the canvas cloth a slightly unpleasant smell is sometimes perceptible, but care should be taken not to reject the meat without further examination, as the smell may only be a surface smell caused by the cloth. When this is removed the fore and hind quarters should invariably be cut through in the ordinary manner, when, if any taint exists, it will be easily detected.

Frozen Meat.—Frozen beef is imported largely from Australia and South America. This beef has been frozen hard at a temperature from 10° to 20° F. as soon as the animal heat has left the carcasses. It can easily be distinguished, before it is thawed, by its cold, hard touch. The fat is not stained, as in the case of refrigerated meat.

When frozen meat has been thawed, the outside will have a wet, par-boiled appearance, and there will be oozing and dripping of liquid from the meat. The fat is of a deadly white colour. The flesh has a uniform pink appearance owing to diffusion of the colouring-matter of the blood, and on a fresh section being made, the watery condition will be very apparent; this loss of juice must be, more or less, deteriorating to its quality. Frozen beef is at present excluded from army contracts.

Frozen mutton comes generally from Australia and New Zealand; being naturally drier than beef, it suffers but little deterioration in the freezing process. It is allowed in army contracts, because, being frozen in an unquartered condition, the meat juice has no chance of escaping.

Salt Meat.—It is not at all easy to judge salt meat, and the test of cooking must often be employed. The following points should be attended to:—

(*a*) *The salting has been well done, but the parts inferior.*—This is at once detected by taking out several pieces; those at the bottom of the cask should be looked at, as well as those at the top.

(*b*) *The salting well done, and the parts good, but the meat old.*—Here the extreme hardness and toughness, and shrivelling of the meat, must guide us. It would be desirable to have the date of salting placed on the cask of salt beef or pork.

(*c*) *The salting well done, but the meat bad.*—If the meat has partially putrefied, no salting will entirely remove its softness; and there may even be putrefactive odour, or greenish colour. A slight amount of decomposition is arrested by the salt, and is probably indetectable. *Cysticerci* are not killed by salting, and can be detected. Measly pigs are said to salt badly, but according to Gamgee this is not the case.

(*d*) *The salting badly done, either from haste or bad brine.*—In both cases signs of putrefaction can be detected; the meat is paler than it should be; often slightly greenish in colour, and with a peculiar odour.

It should be remembered that brine is sometimes poisonous; this occurs in cases where the brine has been used several times; a large quantity of animal substance passes into it, and appears to decompose. The special poisonous agent has not been isolated, but is probably a ptomaine.

Microscopic Examination of Meat.—In the flesh of cattle or of the pig, *Cysticerci* may be found. *Cysticercus cellulosæ* of the pig gives the meat a pale flabby appearance, making it soft and apparently dropsical. The cysts are generally located in very large numbers in the liver, giving that organ on section a mottled appearance. They are generally visible to the naked eye as small round bodies; when placed under a microscope with

low power, their real nature is seen; they are sometimes so numerous as to cause the flesh to crackle on section. The smallest *Cysticercus* noticed by Leuckart in the pig was about $\frac{4}{100}$ths of an inch long and $\frac{3}{100}$ths broad; but they are generally much larger, and will often measure to $\frac{2}{10}$ths or $\frac{3}{10}$ths or $\frac{3}{4}$ths of an inch. In some countries they are extremely common in cattle (*Cysticercus bovis*), and have been a source of considerable trouble in India. The muscles of the haunch are those most frequently affected. *Cysticercus* of the ox produces in man *Tænia mediocanellata*. Oldham describes *Cysticercus tenuicollis* (from *Tænia marginata* of dogs) as common in the sheep of the Punjab; it has four suckers and a double coronet of 32 hooks. In diagnosing Cysticerci of pork the hooklets should always be seen.

Trichinæ may be present in the flesh of the pig; if encapsuled they will be seen with the naked eye as small round specks; but very often a microscope is necessary. A power of 25 to 50 diameters is sufficient. The best plan is to take a thin slice of flesh; put it into liquor potassæ (1 part to 8 of water), and let it stand for a few minutes till the muscle becomes clear; it must not be left too long, otherwise the Trichinæ will be destroyed. The white specks come out clearly, and the worm will be seen coiled up. If the capsule is too dense to allow the worm to be seen, a drop or two of weak acetic acid should be added. If the meat is very fat, a little ether or benzine may be put on it in the first place. The parts most likely to be infected are said to be the muscular part of the diaphragm, the intercostal muscles, and the muscles of the eye and jaw. In diagnosing Trichinæ, the coiled worm should be distinctly seen.

The so-called *Psorospermia*, or Rainey's capsules, must not be mistaken for Trichinæ, nor indeed with care is error possible. These are small, almost transparent bodies, found in the flesh of oxen, sheep, and pigs. They are in shape oval, spindle-shaped, or sometimes one end is pointed and the other rounded, or they are kidney-shaped. The investing membrane exhibits delicate markings, caused by a linear arrangement of minute, hair-like fibres, which are stated to increase in size as the animal gets older. Sometimes they are pointed, and the appearance under a high power is as if the investment consisted of very delicate, transparent, conical hairs, terminating in a pointed process. The contents of the cysts consist of granular matter, the granules or particles of which, when mature, are oval, and adhere together, so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$th to $\frac{1}{4}$th of an inch. They are usually narrow; they lie within the sarcolemma and appear often not to irritate the muscle.

Up to the present time no injurious effect has been known to be produced on men by these bodies, notwithstanding their enormous quantities in the flesh of domestic animals, nor have they been discovered in the muscles of men. But in pigs these bodies sometimes produce decided illness; besides general signs of illness, there are two invariable symptoms, viz., paralysis of the hind legs, and a spotty or nodular eruption. In sheep, they have been known to effect the muscle of the gullet, and produce abscesses, or what may be called so, viz., swellings sometimes as large as a nut, and containing a milky, purulent-looking fluid, with myriads of these capsules in it. Sheep affected in this way often die suddenly.

Diseases arising from altered Quality of Meat.—A very considerable quantity of meat from diseased animals is probably brought into the market, but the amount is uncertain.

1. *The flesh of apparently healthy animals may produce poisonous symptoms.*—Among the *Mammalia* the flesh of the pig sometimes causes diarrhœa. The flesh is probably affected by the unwholesome garbage on which the

pig feeds. Sometimes pork, not obviously diseased, has produced choleraic symptoms. In none of these cases has the poison been isolated.

2. *The flesh of healthy animals, when decomposing*, is eaten sometimes without danger ; but it occasionally gives rise to gastro-intestinal disorder—vomiting, diarrhœa, and great depression ; in some cases severe febrile symptoms occur, accompanied by marked cerebral complications. Cooking does not appear entirely to obviate these effects.

Sausages, and pork-pies, and even beefsteak-pies, sometimes become poisonous from the formation of a ptomaine. The symptoms are severe intestinal irritation, followed rapidly by nervous depression and collapse. Neither salts nor spices hinder the production of this poison.

If the meat is kept in dark, damp, and unventilated places, to which sewer gases can gain access, the probability of the development of poisonous properties in the meat is largely increased. In many cases of meat poisoning this fact has been clearly brought out. The remedy for this is obvious.

Ballard reported two remarkable cases of poisoning by ham and hot baked pork. The first occurred at Welbeck in 1880, and the second at Nottingham in 1881. In both instances a number of persons who partook of the meat were taken ill, and some died. Klein examined the meat, and found it loaded with bacilli, which were also found in the organs of the fatal cases. Guinea-pigs and mice, inoculated with the fluids of the body, died with pneumonia and peritonitic symptoms.

Another case of sausage poisoning, which occurred at Chester, was recorded by Ballard, presenting somewhat different characters. The symptoms were those of gastro-intestinal irritation, which passed off, but was followed by pneumonia, that proved fatal. No *post-mortem* examination could be made. In the Welbeck and Nottingham cases there was an incubation period ; in this case the illness came on at once—in the former the poison was probably a specific micro-organism ; in the latter an organic chemical poison.

Many similar cases have since been recorded, all of which were associated with the development of ptomaines in the meat ; the only common factor being, as stated above, the insanitary conditions under which the meat was kept.

3. *The fresh and not decomposing flesh of diseased animals* causes in many cases injurious effects. Considerable difference of opinion, however, exists on this point, and it would seem that a more careful inquiry is necessary. The probability is that, when attention is directed to the subject, the effect of diseased meat will be found to be more considerable than at present believed. At the same time, we must not go beyond the facts as they are known to us, and certainly bad effects have been traced in only a few instances ; perhaps the heat of cooking is the safeguard.

The flesh of animals killed on account of *accidents* is usually dark and discoloured by reason of not having been bled ; the thoracic and abdominal walls are stained from contact with viscera ; the odour is offensive, and there is discoloration from incipient decomposition. Most meat of this class must always be condemned. If the injuries are localised, and the animal at once slaughtered, the carcass being properly dressed, the undamaged parts are normal in condition, and may be eaten without injury.

If an animal is killed by *lightning*, the flesh putrefies so rapidly that it cannot escape detection ; the same applies to apoplexy. In each case the peritoneum and pleura are discoloured, the flesh has a pungent odour and a dark colour gorged with blood, and the whole exterior is dark red. The flesh of *over-driven* animals is harsh in character and wanting in that juicy

characteristic noticed in good, well-fed animals which have been rested before slaughter.

Carcasses of animals slaughtered before, during, or immediately after *parturition* are not necessarily unfit for food. If there is evidence of extravasation or inflammation of the pelvic cavity, and the flesh elsewhere pale and livid and ill-set, it should be condemned. But if it be a case of abnormal presentation, and the animal be slaughtered and properly bled and dressed, the flesh may be perfectly fit for consumption.

Meat is not apparently altered in the *early stage* of acute inflammatory disease, and it is said that some of the primest meat in the London market is taken from beasts in this condition ; it is not known to be injurious, but it has been recommended that the blood should be allowed entirely to flow out of the body and not be used in any way.

Cattle, pigs, poultry and rarely sheep are all liable to be affected with tubercle, but it is in cattle, and more especially milch-cows, that tuberculosis is met with. The organs most frequently affected are the lungs, liver, kidneys and brain, and, in the cow, the udder. The muscles appear to be rarely affected.

From the appearance presented by tubercular deposits in the serous linings of the thorax and abdomen, animals suffering from well-marked symptoms are said to have the " grapes "—the little nodules in the substance of organs resemble fruit-stones, and are called " kernels." There may be no visible symptom of the disease in the animal, except in the case of an acute attack, in which case there is always fever and rapid wasting of the body. When the disease attacks the external organs, such as the udder, there is generally no constitutional disturbance ; this is much more likely to be present when the internal viscera are affected, so that an animal may be extensively diseased and yet exhibit no symptom to call for special attention. The question of the use of the flesh, as of the milk, of tuberculous animals has been extensively debated. From the nature of the case there is great difficulty in obtaining direct evidence of the transmission of the disease from animals to man, but recent experimental work indicates the undoubted possibility of this transmission. In general tuberculosis the flesh should certainly not be eaten, but in other cases, where the tuberculosis is not general, the usual practice is to destroy only affected internal organs and the lymphatic glands.

The Report of the Royal Commission appointed to inquire into the effect of food derived from tuberculous animals clearly indicates that the danger is a real one, especially with regard to the meat of tuberculous bovines. Martin's evidence, in particular, shows that a great difficulty exists with regard to meat, inasmuch as a number of butchers are very careless in the cutting up of carcasses partially affected with tuberculosis. Matter finds its way to the knives used, and this is transferred to joints which would otherwise remain untainted. Roasting before a fire was the least, and boiling the most, effective method of cooking the flesh.

The Royal Commission on Tuberculosis, 1896–98, made the following recommendations :—

(1) When there is miliary tuberculosis of both lungs.
(2) When tuberculous lesions are present on the pleura and peritoneum.
(3) When tuberculous lesions are present in the muscular system, or in the lymphatic glands embedded in or between the muscles.
(4) When tuberculous lesions exist in any part of an emaciated carcass.

The entire carcass and all the organs may be seized.

(1) When the lesions are confined to the lungs and the thoracic lymphatic glands. (2) When the lesions are confined to the liver. (3) When the lesions are confined to the pharyngeal lymphatic glands. (4) When the lesions are confined to any part-combination of the foregoing, but are collectively small in extent.	The carcass, if otherwise healthy shall not be condemned, but every part of it containing tuberculous lesions shall be seized.

In view of the greater tendency to generalisation of tuberculosis in the pig, they considered that the presence of tubercular deposit in any degree should involve seizure of the whole carcass and of the organs. In respect of foreign meat, seizure must ensue in every case where the pleuræ have been stripped.

Epidemic pleuro-pneumonia is a disease peculiar to the ox, and is a contagious inflammation of the lungs and pleura; but it has never been transmitted to other than bovine animals, its effects are localised in the lungs alone, and even in these organs the disease is a limited one. In the advanced stages, and when a large area of lung tissue is destroyed, with extensive pleurisy, the flesh becomes altered in colour and consistence. The rule is to pass the carcasses of animals affected with pleuro-pneumonia as marketable and innocuous, if they present no departure from natural conditions.

Anthrax occurs in cattle, sheep, horses, and sometimes pigs; the disease is rapidly fatal, the animal often dying within a few hours. It is both infectious and inoculable, the specific micro-organism being present in the blood and spleen. This organ is usually much enlarged, congested, dark in colour, and sometimes found to be ruptured—a condition which gives rise to the name of "splenic apoplexy."

"Black quarter" or "quarter ill" is an anthracoid disease characterised by hæmorrhagic effusion into the subcutaneous or intermuscular tissues of one or both of the anterior or posterior extremities. This disease is very infectious and fatal. Characteristic bacilli are found in the extravasations and in the abdominal visera. The flesh of animals infected with either anthrax or quarter ill should be considered as unfit for food. Every part of the carcass should be destroyed by fire.

Braxy.—This disease is very prevalent among sheep in the west of Scotland during the late autumn and early winter months. By far the greater number of sheep attacked are the first year's animals. The course of the disease is rapid and the *post-mortem* appearances are marked by sero-sanguineous effusions in the various body cavities, inflammation of the fourth stomach and the production of much gas in the connective tissues. The disease is caused by a spore-bearing anaerobic bacillus closely allied to that of malignant œdema and quarter ill. The flesh of sheep which have died of true braxy should not be eaten. The carcasses should be destroyed by fire when possible.

Acute rheumatism in cattle is sometimes known as "joint ill." The serous fluid effused into the joints may become purulent, and abscesses may sometimes be found in the neighbourhood of the affected joints. The meat becomes dropsical and the carcasses of animals so affected are usually unfit for human food.

Small-pox of Sheep.—The flesh has a peculiar nauseous smell, and is pale and moist. It produces sickness and diarrhœa, and sometimes febrile symptoms. The meat of animals suffering from this disease is soft, wet, and pallid, it has a disagreeable odour, and should be condemned as unfit for food.

Foot-and-mouth Disease.—Lévy states that at different times aphthous disease has prevailed among cattle both at Paris and Lyons without the sale of the meat being interrupted or giving rise to bad results. Occasionally in chronic cases, or when the infected animals have been exposed to wet or neglect, the flesh may become deteriorated to an extent which renders it unfit for food. In ordinary cases the condition of the carcass differs in no respect from that of one which has been slaughtered in perfect health. Of course the affected parts should not be used for food.

Rinderpest.—The evidence is not conclusive that the flesh of animals, dead of cattle plague, is unfit for food, but the majority of experts consider it to be so.

Swine fever, called also "hog cholera," "soldier," &c., is a very fatal disease amongst swine. It is very difficult to detect in the early stages of its development, and in the varying modes of its onset and progress shows an analogy with typhoid fever in man. The *post-mortem* appearances are also somewhat similar—ulceration and inflammation of alimentary canal, most commonly the large intestine, being present. This disease is one which renders the flesh of the animal unfit for consumption.

Parasitic Diseases.—Cysticercus cellulosæ of the pig gives rise to a disease known as "measles" and produces *Tænia solium* in man, and that of the ox and cow *Tænia mediocanellata.* These entozoa often arise from eating the raw meat, but neither cooking nor salting ensure protection, though they may lessen the danger. According to Delpech, smoking appears to kill Cysticerci, and so does a temperature of 212° F. Lewis found that a much lower temperature sufficed, and considered there was no danger if the cooking were well done, as the temperature of efficient cooking is never below 170° F.

Trichina spiralis in the pig gives rise to the condition of trichinosis caused by the wanderings of the young Trichinæ. The affection is highly febrile, resembling enteric fever, or even typhus, or acute tuberculosis, but attended with excessive pains in the limbs and œdema. Boils are also sometimes caused. The eating of raw trichiniferous pork is the chief cause, and the entozoon is not easily killed by cooking or salting. A temperature of 144° to 155° F. kills free Trichinæ, but encapsuled forms may demand a greater heat. During cooking a temperature which will coagulate albumin renders Trichinæ incapable of propagation, or destroys them. As a practical rule, it may be said that if the interior of a piece of boiled or roasted pork retains much of the blood-red colour of uncooked meat, the temperature has not been higher than 150° F., and there is still danger. Intense cold and complete decomposition of the meat do not destroy Trichinæ. Hot smoking, when thoroughly done, does destroy them ; but the common kinds of smoking, when the heat is often low, do not touch Trichinæ.

Distomum Hepaticum in Sheep.—It is said that many persons will eat freely of, and even prefer, the liver of the sheep full of flukes. No direct evidence has been given of the production of disease from this cause, at least in this country. The affected liver should in all cases be destroyed and the carcass should be condemned if it be deteriorated. In Iceland, *Echinococcus* disease, which affects a large number of persons, is derived from sheep and cattle, who, in their turn, get the disease from Tænia of the dog (Leared and Krabbe). Wet seasons are conducive to the spread of the disease, as the eggs and embryo of the parasite are developed in water.

Glanders and *farcy* in horses do not appear to produce any injurious effects when such horse-flesh is eaten as food. In 1870, during the siege of

Paris, large quantities of flesh from horses with farcy and glanders were eaten without producing ill effects.

Medicines, especially *antimony*, given to the animals in large quantities, have sometimes produced vomiting and diarrhœa. *Arsenic*, also, is occasionally given, and the flesh may contain enough arsenic to be dangerous.

In certain outbreaks of disease traceable to the consumption of meat of doubtful antecedents the *Bacillus enteritidis* of Gärtner has been found in or upon the implicated food.* A variety of the same organism was discovered by Durham in the Hatton epidemic and by Delepine under similar circumstances at Derby.† A few hours after the consumption of the food serious illness is produced, attended by vomiting, diarrhœa and collapse. MacConkey has reported similar cases.‡ Van Ermenghen investigated a curious outbreak of poisoning due to the consumption of raw pickled ham, and succeeded in isolating an anaerobic spore-bearing bacillus from the meat and from the spleen of fatal cases. The bacillus has been named the *B. botulinus*. In the outbreak of food poisoning at Chadderton, caused by the consumption of veal and pork pies, the symptoms were very similar to those produced by Gärtner's bacillus. The outbreak was investigated bacteriologically by Durham, who found that the blood taken from patients gave positive agglutination reactions with certain of the varieties of the *B. enteritidis*, especially with the variety which was isolated from the Hatton epidemic. The inference is that the Chadderton epidemic was caused by a variety of the same micro-organism, though the bacillus itself was not isolated.

In nearly all these cases the evidence is insufficient to affirm that the infective micro-organism was originally in the food or flesh. On the other hand, there were usually coincident insanitary conditions suggestive of every possiblity of contamination, some time after cooking.

LAW RELATING TO UNSOUND FOOD AND HORSE-FLESH.

In England and Wales.—Under the Public Health Act, 1875, the Medical Officer of Health and Inspector of Nuisances have power, at all reasonable times, including Sunday, to examine or inspect any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk exposed for sale, or deposited for the purposes of sale, or of preparation for sale, and intended for the food of man; and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate (section 116), who may order it to be destroyed or so disposed of as to prevent it from being exposed for sale or used for the food of man, and inflict a penalty not exceeding £20, or a term of imprisonment of not more than three months (section 117). The proof that it was not intended for the food of man rests with the person charged. Any person hindering these officers from inspecting meat, &c., is subject to a penalty of £5 (section 118). On complaint made by oath by any officer of a Sanitary Authority that there is reason to believe that there is kept or concealed on any premises any articles to which these sections apply, a justice may grant a search-warrant, and any person hindering the execution of this warrant is liable to a penalty of £20 (section 119).

* Durham: "Outbreaks due to Meat Poisoning," *Brit. Med. Journal*, December 17, 1898.
† Morgan: "The Micro-organisms of Meat Poisoning," *Brit. Med. Journal*, June 10, 1905.
‡ MacConkey: "Note on Some Cases of Food Poisoning," *Journal of Hygiene*, October 1906.

Under the Sale of Food and Drugs Act, 1899, the expression "food" shall include every article used for food or drink by man, other than drugs or water, and any article which ordinarily enters into or is used in the composition or preparation of human food; and shall also include flavouring matters and condiments. Under this Act, margarine and margarine cheese, adulterated or impoverished butter, milk, or cream, machine-skimmed milk or skimmed milk, or any adulterated or impoverished article of food to which His Majesty may by Order in Council direct that this section shall be applied, must not be imported unless the same be imported in packages or receptacles conspicuously marked with a name or description indicating that the article has been so treated.

In markets and fairs under the control of a Sanitary Authority the sale of unwholesome meat or provisions is subject to similar provisions under section 15 of the Market and Fairs Clauses Act, 1847, which is incorporated with the Public Health Act, 1875. Where the market or fair does not belong to the Local Authority the above provisions will not apply, unless a local Act is in force, with which the Market and Fairs Clauses Act is incorporated. A Sanitary Authority can make bye-laws for preventing the sale of unwholesome provisions in a market or fair by section 42 of the Act of 1847, also incorporated in the Public Health Act, 1875; but owing to the stringency of sections 116 to 119 of this latter Act, these bye-laws will be rarely necessary.

In London, under section 47 of the Public Health (London) Act, 1891, the provisions as to the sale of unsound food are somewhat more stringent. The London Act not only closely follows the lines of section 28 in Part III. of the Amendment Act, 1890, but renders the offender liable, on conviction, to a fine not exceeding £50, or imprisonment for six months with or without hard labour. The section further enforces the liability of the previous vendor of the food, and also renders any one obstructing an officer acting under a warrant for entry within twelve months after a previous conviction for obstruction, or evidently with intent to prevent detection, liable to imprisonment for a month in lieu of fine. The Sanitary Authority have further the duty placed upon them of removing unsound food, as if it were trade refuse, on the receipt of written notice from a person having possession of the same.

In Scotland, under section 43, Public Health (Scotland) Act, 1897, any medical officer or Sanitary Inspector, or any veterinary surgeon approved for the purposes of this section by the Local Authority, may inspect and examine (1) any animal, alive or dead, intended for the food of man, which is exposed for sale, or deposited in any place, or in the course of transmission for the purpose of sale or of preparation for sale; and (2) any article, whether solid or liquid, intended for the food of man, and sold or exposed for sale, or deposited in any place, or in the course of transmission for the purpose of sale or of preparation for same; the proof that the same was not exposed or deposited or in course of transmission, or was not intended for the food of man, resting with the person charged; and if any such animal or article appears to such medical officer or Sanitary Inspector to be unfit for the food of man, he may seize and carry away the same himself or by an assistant in order to have the same dealt with summarily by a sheriff, magistrate, or justice. In the burghs, there is power to "seize and destroy diseased cattle, whether offered for sale or not, and to prosecute the original sellers of diseased meat or animals intended for human food, whether within or without the burgh" (Burgh Police (Scotland) Act, 1892, sections 428–9).

In Ireland.—Sections 132 to 135 of the Public Health (Ireland) Act, 1878, contain very similar provisions as to unsound food as are contained in the corresponding English Act, with the addition of butter in the classification of articles. Section 42 of the Markets and Fairs Clauses Act, 1847, is not incorporated in the Irish Act, but section 108 of this latter Act enables an urban authority to make bye-laws for the prevention of the sale of unwholesome food in all markets and fairs belonging to it. Section 15 of the Markets and Fairs Clauses Act, 1847, " applies only in the case of an urban authority." With these exceptions, the Irish and English enactments in respect of this matter are similar.

The provisions controlling the sale of horse-flesh for human food are the same in all parts of England, Wales, Scotland, Ireland, and the Metropolis. They are contained in the Sale of Horse-flesh, &c., Regulation Act, 1889, which defines " horse-flesh " to be such flesh cooked or uncooked, alone or mixed with other substances, and includes the flesh of asses and mules (section 7).

This Act (section 1) provides that the flesh of horses, asses, or mules must not be sold or kept for sale for human food, except in a shop or stall over or upon which is placed conspicuously, in legible characters 4 inches long, an announcement that horse-flesh is sold there. It also prohibits the sale of horse-flesh for human food to any purchaser asking for other meat, or for a compound article not usually made of horse-flesh (section 2). Any person offending against these provisions is liable to a penalty not exceeding £20, to be recovered summarily (section 6). The machinery and procedure for the inspection, obtaining of a search-warrant, seizing and taking of suspected meat before a justice, is similar to that contained in sections 116 to 119 of the Public Health Act, 1875, and already detailed under the heading of unsound meat. The principal point of difference is that the power of inspecting is given not only to the Medical Officer of Health and Sanitary Inspector, but also to any other officer of the Sanitary Authority (sections 3 to 5).

In London, the various Borough Councils, and the Corporation of the City, are the Local Authorities for the administration of this Act. In the rest of England and Wales, and in Ireland, the Local Authorities are the urban and rural Sanitary Authorities under the respective Public Health Acts. In its application to Scotland, the expression " justice " includes a Sheriff and Sheriff-Substitute, and " Local Authority " means any Local Authority authorised to appoint a Public Analyst under the Sale of Food and Drugs Act, 1875.

FISH.

Of the great nutritive value of fish as an article of diet, there can be no doubt. The varieties which are used as food are almost infinite, and whole populations appear to exist on it. It is less satisfying and not so stimulating as the flesh of animals, but is easily digested. Its use is greatest in those places where it is readily caught, and recommends itself on account of its abundance and cheapness. Lately it has been said that fish diet predisposes to diseases of the skin, especially leprosy ; but the evidence on this point is not by any means conclusive ; indirectly this connection, or alleged predisposition, may be associated with the poverty prevalent in those countries where the poorer classes are obliged to subsist altogether on this class of food, and where meat is never partaken of, and indicates that fish should not alone be the source from which nitrogenous food is taken.

The flavour and digestibility of fish depend on the amount of fat it contains, which varies in different species, the white fish, as sole and whiting containing a small proportion, whereas the salmon and eel have a large amount. As a rule, white fish have least oil.

The following table gives the composition per cent. of some of the most important kinds :—

	Water.	Proteins.	Fat.
Salmon (Pavy)	77·00	16·10	5·50
Herring	80·71	10·11	7·11
Sole	86·14	11·94	0·25
Mackerel	68·70	23·50	6·76
Eel (Letheby)	75·00	9·90	13·80
White fish (Pavy)	78·00	18·10	2·90

Inspection of Fish.—As in the case of animals, fish when eaten should be fresh. A fresh fish is firm and stiff; the drooping or not of its tail is a fair criterion of staleness in a fish. Flat fish keep better than herrings or mackerel. Cod, haddock, and whiting keep the best, particularly if rinsed with salt water and stored in a cool place. All fish intended for food should be unbruised, unbroken, and clean. If the scales are dull and damaged it is very suggestive of either ill-usage or staleness; softening in places indicates the same.

It is an established fact that decomposition in the surface fishes, such as herrings, mackerel, sprats, mullet, pilchards, &c., is extremely rapid. Ground fish, like halibut, skate, cod, sole, plaice, turbot, &c., decompose much less rapidly, and if properly packed remain fresh and fit for human food from seven to ten days after being taken from the sea. Fish which have been ungutted are the most difficult to judge, more especially those with large oily livers. Externally they appear good, the eyes being bright, gills red, but internally they are usually much decomposed.

With strong pressure of the thumb and fingers upon the under side, the deeper flesh readily crushes, leaving the skin only between the fingers. This is an infallible test of unsoundness. Immediately after death the blood of fish becomes congealed. When decomposition sets in, on cutting the fish this blood will run out as a liquid of a dull red colour, giving off an offensive smell. On removing the bones, moreover, each one leaves a dull red mark, showing where the decomposition processes are extending to the more solid portions of the fish. To avoid rapid decomposition, all fish should be at once bled and gutted on being caught; neglect of this procedure is the cause of a very large amount of fish quickly decomposing, and being in consequence condemned as unfit for food.

Shell-fish form not only an important article of food, but are extensively used alive as bait. Mussels and oysters are unfit for food very soon after death. Crabs and lobsters, if boiled a few hours after death, are nearly flavourless, decomposition being much more rapid than if killed just before cooking. No crab may be held in possession or exposed for sale less than 4½ inches across the back, and no lobster less than 8 inches from beak to tail when extended flat, the penalties being in these cases £2 for the first offence, and £10 for the second and every subsequent offence. Under the Crab and Lobster Act, no crab may be consigned for sale with spawn outside attached to the tail, but the lobster may.

Parasites of Fish.—The majority of fishes are infested with different kinds of parasitic worms. As examples of this excessive parasiticism,

von Linstow assigns to the cod nine species of nematode, fifteen cestodes, and five trematodes; the herring is credited with six nematodes, three cestodes, three trematodes; the salmon with five nematodes, nine cestodes, six trematodes. Fortunately, the greater number of these are killed in cooking, while none of them, so far, are known to be parasitic or hurtful to man. The oyster, which is the one fish eaten raw in this country, is at times afflicted with a trematode worm, but we have no evidence to show that it has ever adapted itself to live in man.

The only parasitic worm known, with any certainty, to be conveyed to man through fish is the *Bothriocephalus latus*. The encysted stage of this worm is passed in either the pike or the turbot. These fish, moderately smoked or salted, are, or were till recently, almost the staple food round Dorpat in the Baltic provinces; when eaten, the encysted worms, which are not killed by the processes of preparation, become in their new and appropriate environment the sexual tapeworm; but so far as is known, if eaten by other than the specific hosts, for example, by other fish, they die without assuming the sexual form. Fish, particularly decomposed and some preserved fish, undoubtedly contain various kinds of bacteria. Edington, in reporting to the Scotch Fishery Board, has demonstrated the presence of bacilli as the cause of the red coloration in some salt fish. Experiments made, by various observers, have shown fish to be incapable of tubercular infection even when kept in water largely impregnated with tubercle bacilli.

Poisoning by Fish.—The flesh of apparently healthy fish may produce poisonous symptoms. This is the case with certain species of fish, especially in the tropical seas. There is no evidence that the animal is diseased, and the flesh is not decomposed; it produces, however, violent symptoms of two kinds—gastro-intestinal irritation and severe ataxic nervous symptoms, with great depression and algidity.

The little herring (*Clupea harengo minor*), the Indian dory (*Zeus gallus*), the pilchard, the sea-breams (*sparidæ*), the barracudas (*sphyrænidæ*), the wrasses (*labridæ*), and others, have been known to produce these effects. Some of these fish are unwholesome only during the breeding season, while many tropical fish owe their poisonous qualities to the fact that they feed on poisonous medusæ and corals. Mackerel have been known to produce poisonous symptoms, probably owing to the fish undergoing rapid decomposition. When the fish is cooked immediately after being caught, it does not appear to produce any bad effects. If possible, some means should be adopted to retain fish alive until they are required for the table; and they should be eaten the earliest moment after capture.

Oysters and shell-fish (even when in season) have been known to produce poisonous symptoms. The production of nettle-rash in some persons from eating fresh shell-fish is not uncommon, and if at all decomposed they produce more marked symptoms.

Shell-fish and Infection.—A considerable literature has accumulated in recent years showing the intimate relation between shell-fish and certain forms of infective disease. Mussels and oysters, especially if taken from beds to which sewage gains access, have undoubtedly given rise to enteric fever among consumers. Under certain circumstances, the same shell-fish are equally able to transmit the infection of cholera. In 1894, an outbreak of enteric fever among the students at the Wesleyan University, Connecticut, was traceable to the consumption of raw oysters taken from a bed within 100 yards of sewers emitting the drainage of houses in one of which were two persons suffering from enteric fever. In 1896,

Chantemesse reported an outbreak of disease at Saint-André-de-Saugonis, due to the consumption of oysters which had been stored in sewage-contaminated water. In the same year, Bulstrode and Klein furnished a report to the Local Government Board upon oyster culture in relation to disease. Experiments by Klein gave results which were thus summarised by Thorne-Thorne in this introduction to the Report :—

(1) The cholera vibrio, and still more the typhoid bacillus, are difficult of demonstration in sewage known to have received them.

(2) Both these organisms may persist in sea-water tanks for two or more weeks.

(3) Oysters from sources which appeared to be free from risk of sewage contamination exhibited none of the bacteria, specific or otherwise, which are commonly regarded as being concerned with sewage.

(4) Oysters from a few out of numerous batches derived from sources where they did appear to be exposed to risk of sewage contamination were found to exhibit colon bacilli.

(5) In one case in which the circumstances were especially suspicious, Eberth's typhoid bacillus was found in the mingled body and liquor of the oyster.

Since then there have been several outbreaks of enteric fever and gastro-enteritis due to eating infected oysters. The more notable were those following the mayoral banquets at Winchester and Southampton in 1902, which Bulstrode traced to the eating of oysters grown on beds polluted with sewage. Klein found *B. coli*, *B. enteritidis sporogenes* and certain organisms allied to the Gärtner bacillus in oysters from the same layings. Similar micro-organisms are readily isolated from oysters or mussels derived from polluted beds, but in adjudicating upon the question whether particular shell-fish have given rise to any infective disease, topographical evidence as to actual pollution of the laying beds should be deemed more reliable than mere bacterial evidence.

Oysters or other shell-fish taken from contaminated beds should be deposited for a time in pure sea-water before consumption, as, if so placed, they appear to have the power of clearing themselves of infective germs. Further legislative powers are needed to enable Local Authorities to inspect and control oyster layings or shell-fish beds and to prevent the sale in their district of molluscs derived from sewage-contaminated sources.

The processes of drying, pickling, salting, and smoking are employed for the preservation of fish. Each process considerably lessens its digestibility, and therefore unsuits it for either the dyspeptic or the invalid. Moreover, unless the fish, originally, be thoroughly sound, there is reason to believe that preservation processes may aggravate the capabilities of fish to produce irritant symptoms ; upon this point, however, our present knowledge is very inexact.

EGGS.

Though both ducks' eggs and those of sea fowl are used, those of the hen are the eggs usually eaten as food. The average weight of a hen's egg is about 58 grammes, or about 2 ounces avoir. — 10 parts are shell, 60 white, and 30 yolk. The white contains chiefly egg-albumin, with a trace of fat and a small proportion of salts ; the yolk contains a globulin (vitellin), a large quantity of fat, and more salts than the white. Ducks' eggs contain more fat than do those of the hen. Traces of grape-sugar have been found in some egg yolks, while of the mineral constituents iron

in organic combination is the most important. In the yolk, potassium salts and phosphates predominate; in the white, sodium salts and chlorides are in excess. Gautier claims to have isolated albumoses and ptomaines from eggs; both these bodies are probably the result of decomposition processes. The following table represents the average composition of ordinary hens' eggs:—

	Water.	Proteins.	Fats.	Salts.
Whole egg (with shell) .	73·50	13·50	11·60	1·20
White of egg . . .	85·50	12·87	0·25	0·63
Yolk of egg . . .	51·03	16·12	31·39	1·01

For preservation, eggs are packed in sawdust or salt, or are covered with gum, butter, or oil, or placed in lime-water to which a little cream of tartar has been added. Boiling for half a minute also keeps them for some time; in fact, anything which excludes air will preserve them. The lime-water is said to give them a peculiar taste and makes the albumin more fluid.

Eggs do not appear to suit all people, and if even slightly decomposed should not be eaten. According to Rubner, about 20 per cent. of the proteins from eggs appears unabsorbed in the fæces, while rather more of the fat also escapes unutilised.

MILK.

Milk not only constitutes the chief diet for children up to some eighteen months of age, but also enters very largely into the food of adults. It may be regarded as nothing more than an emulsion of fat containing proteins, salts, and carbo-hydrates in solution in water. The average composition of milk per 100 parts from the chief sources as used by man is shown in the following table:—

Kind of Milk.	Specific Gravity.	Total Solids.	Proteins.	Fats.	Carbo-hydrate.	Salts.	Water.	Proportion of nitrogenous to non-nitrogenous constituents.
Human . .	1027	12·60	2·29	3·81	6·20	0·30	87·40	as 1 is to 4·4
Cow's . .	1032	12·83	3·55	3·69	4·88	0·71	87·17	„ 1 „ 2·5
Mare's . .	1035	9·21	2·00	1·20	5·65	0·36	90·79	„ 1 „ 3·4
Ass's . .	1026	10·40	2·25	1·65	6·00	0·50	89·60	„ 1 „ 3·4
Goat's . .	1032	14·30	4·30	4·78	4·46	0·75	85·71	„ 1 „ 2·0
Buffalo's . .	1032	18·60	6·11	7·45	4·17	0·87	81·40	„ 1 „ 1·9

Although all the above are used at times by man for food, the most important kinds are undoubtedly human milk and cow's milk; and these differ from each other in some essential particulars. As seen by the preceding table, while there is more carbo-hydrate in human milk than in cow's, the reverse is the case with the proteins and salts; the fat being much the same in both. Ass's milk, except in regard to its fat, is most like human milk; but mare's milk contains even less fat and protein than the ass's; while, on the other hand, milk from both the goat and buffalo are very rich in fat.

The composition of a milk would appear to depend upon the rate of growth of the animal for which it is intended, and the variations occur

chiefly in regard to the proteins and the salts. In proportion as these together are increased in milk, so the time taken to double the weight of the animal is diminished.

The proteins of milk consist of casein or caseinogen and an albumin agreeing in general features with ordinary serum albumin, but which, since it differs in its solubilities and rotatory power from serum albumin, has been called lactalbumin. Caseinogen, under the action of rennet, is split up into casein and another protein which is not coagulated by heat, and appears to be allied to peptone or albumose. Caseinogen and lactalbumin, when suspended in water, are coagulated by heat,but not under natural conditions, owing to the alkalinity of the milk. Hence milk when boiled does not coagulate as a whole, though in the superficial layers exposed to the air, changes take place by which a film, derived partly from the lactalbumin and partly from caseinogen, appears on the surface ; if this be removed a fresh portion undergoes the same change.

The salts of milk are both numerous and various, being composed of all the mineral constituents necessary to the growing body. They are chiefly calcium phosphate, potassium and sodium chlorides, with a small quantity of magnesium phosphate. The calcic salt appears to play a peculiar part in determining the insolubility of the curd produced by rennet. In the absence of this salt both the products of the action of the ferment remain in solution. Citric acid is a normal constituent of the milk of various animals. In human milk, the quantity is about 0·5 gramme to the litre, in cow's milk about 1·5 grammes. It does not appear to be dependent upon citric acid present in the food. Minute amounts of nitrogenous bases and a starch-converting ferment also occur.

The fat of milk is nothing more than minute suspended oil globules which, upon standing, rise slowly to the surface, forming cream. One part of cream may be said to correspond roughly to 0·3 of fat ; the proportion of cream yielded by a pure milk varies, but may be said to average 8 per cent., being as high as 14 in some cases, and as low as 6 in others. The amount found in a given time is no measure of the richness of the milk ; water added to milk causes a more rapid separation of the cream. When milk is subjected to centrifugal action, as in the *separator*, a much larger proportion of cream is obtained than by the mere skimming process. As a result of this, skim milk contains 1 per cent. of fat, while separated milk has practically none.

The carbo-hydrate of milk is a peculiar sugar, somewhat like cane-sugar, and called lactose or sugar of milk, $C_{12}H_{22}O_{11}+H_2O$. It is a hard variety of sugar, grating under the teeth, and tastes but slightly sweet ; it rotates polarised light $+61^\circ{\cdot}5$. This body, like other sugars, undergoes fermentation under the influence of micro-organisms, and one especially, called the *Bacterium lactis*, abounds in dairies and other places where milk is kept. This micro-organism converts the milk-sugar into lactic acid, while at the same time the proteins are partly decomposed and partly coagulated, the milk itself becoming sour with enclosure of the fat in the coagulated casein. The precipitation of casein by lactic acid must not be confounded with the formation of casein from caseinogen by ferment action.

After the lactic-acid fermentation of milk has set in, the casein gradually decomposes, and, during the early decomposition of the proteins, very frequently highly poisonous compounds are formed, which are often the cause of the violent poisonous effects at times produced by ice-creams and other articles of food into the making of which milk enters.

Many other micro-organisms produce coagulation of milk, notably the *Bacillus butyricus* of butyric acid fermentation. Some others have the

power of changing the colour of milk, particularly if lactic acid fermentation has occurred. Thus the *Bacillus cyanogenus* causes blue milk; the *Bacillus synxanthum* causes yellow milk; the *Micrococcus prodigiosus* produces red milk; while some others cause milk to become ropy and stringy. In nearly all these cases, the milk is apt to cause diarrhœa, and is unsuited for food. Alcoholic fermentation of the milk-sugar can also be set up by certain micro-organisms. "Koumiss" is the result of the alcoholic fermentation of mare's milk, and "Kéfir" that of the milk of the cow, goat, and sheep.

Boiling of milk produces some obscure changes in the sugar, and greater coalescence of the fat globules. Micro-organisms and ferments are at the same time destroyed, a fact which explains the better keeping qualities of boiled milk. At 100° C., the calcium citrate is deposited.

As an article of diet, milk holds the highest place. When digested, either by the gastric or pancreatic juices, milk clots, the casein being precipitated as large curds. The curds are subsequently changed to albumoses and peptones by the digestive ferments, a bitter substance being formed, which makes all peptonised milk unpleasant in taste.

For infants, human, mare's, and ass's milk constitute typical foods, the nitrogenous and non-nitrogenous constituents being in the right proportion, or as 1 is to 4·4; whereas, in cow's milk the ratio is as 1 is to 2·5, a fact which renders the milk of the cow, by itself, not a perfect food. This fact is of great practical importance, as if cow's milk is to become a complete and true food for either young children or adults, its non-nitrogenous organic food-stuffs must be increased by the addition of sugar or arrowroot. The artificial approximation of the composition of cow's milk to that of the human being is best carried out in the following manner:—"The cream is separated from a pint of milk, and the casein of one-half of the skimmed milk coagulated with a small quantity of rennet and strained off. To this whey, the cream which has been removed and the rest of the skimmed milk are added. The composition of this artificial human milk varies; it contains on the average a little over 2 per cent. of protein, 4·5 per cent. of fat, 5 per cent. of lactose, and 0·6 per cent. of salts."

To render ordinary cow's milk suitable for infants or others whose digestive powers are feeble, it must be diluted with either water, lime-water, or barley-water; dilution lessening the size of the casein clots and indirectly favouring their digestion. After dilution, sugar should be added to cow's milk to bring it nearer to the human standard; the proportion to be added should be about 30 grammes of lactose to each litre of diluted milk, or about three-fifths of an ounce to each pint. The exact dilution to which the milk should be submitted varies with the child's age; thus, for the first month of life, two parts of water must be added to one of milk; after the second and third months, more milk may be added, until about the sixth month the child attains to undiluted milk. These must be taken only as general statements, as frequently milk needs to be even more dilute. The percentage composition of diluted cow's milk with added lactose may be thus given as quoted by Martin:—

	Water.	Proteins.	Fats.	Lactose.	Salts.	Proportion of nitrogenous to non-nitrogenous food-stuffs—as
Cow's milk with equal parts of water	90·59	1·77	1·85	5·44	0·35	1 : 4
Cow's milk with two parts of water .	92·73	1·18	1·23	4·63	0·23	1 : 4·8

Accepting this statement, and assuming that a child at five months requires about 2 litres of mother's milk daily, representing nearly 45 grammes of protein, 80 grammes of fat, 125 grammes of sugar, and 6 grammes of salts; it would require, therefore, 3 litres of milk diluted with 2 parts of water to obtain similar amounts of the food-stuffs.

In the case of an adult requiring daily 4·59 ounces of protein, 2·96 ounces of fat, and 14·2 ounces of carbo-hydrate, and assuming that 1 litre (35 ounces) of average cow's milk contains 1·24 ounce of protein, 1·29 ounce of fat, 1·7 ounce of lactose, and 0·27 ounce of salts, it would require at least 4 litres or about 7 pints of milk to furnish him with the necessary amount of protein, while at the same time the fats and water would be in excess and the carbo-hydrates deficient.

Variations in the composition of normal cow's milk are of frequent occurrence, and may result not only from the kind of feeding, but also from peculiarities of race, the time since calving, and methods of milking the cow. As evidence of this we find that, in what are really normal milks, the specific gravity may range from 1·027 to 1·034, the water may vary from 85 to 88 per cent., the proteins from 2·5 to 5 per cent., the fat from 2·75 to 6 per cent., the lactose from 3·5 to 6 per cent., and total solids from 11·5 to 15 per cent.

The effect of diet is largely shown by the increase of sugar found in the milk of cows fed upon fodder rich in carbo-hydrates, such as carrots and beetroots. The addition of protein in the diet raises the casein but not the fat. Cows which are fed much upon refuse from breweries and distilleries commonly yield an abundance of milk, but it is simultaneously poor in fats and other solids. Diseased potatoes and turnips in the food of cattle, without actually affecting the goodness of milk, often cause it to smell and taste unpleasantly.

The quantity of milk yielded by a cow, and its proportion of total solids and fats, often vary in opposite directions. Some cows, like the Dutch, which produce an abundance of milk, usually yield low percentages of fat. Alderneys, on the other hand, commonly yield a milk rich in fat; others, like the long-horned cows, yield large quantities of casein. As a rule, the proportion of total solids in a milk is stable. They practically never fall below 11·5, and commonly average between 12 and 13 per cent. Though the fats yielded by the milks of different cows are apt to vary much, the "solids not fat" fluctuate relatively less. These rarely fall below 8·5 per cent., a figure which is now generally accepted as the minimum standard of a pure and normal milk. This question of the variations in the composition of milk is one of some complexity; in every district observations on the average composition of milk need to be collected for the several months of the year, as it is only by mean values for extensive districts or entire counties that we can arrive at any correct opinion, or formulate standards.

In skimmed milk, the proportion of fat varies greatly; extreme figures cannot be given, but the specific gravity usually amounts to from 1·032 to 1·035, unless it has been simultaneously watered. Separated milk, or that which has had its cream removed by a separator, contains from 0·1 to 0·25 per cent. of fat, and has a specific gravity of from 1·033 to 1·036. A mixture of skimmed evening milk and new morning milk, or of milk which has been partially freed from cream, is sometimes sold as "half milk." Its average composition and condition is not easily defined.

The milk secreted in the early stage of lactation, known as colostrum, is very rich in proteins, due probably to an incomplete transformation of the epithelial lining of the ducts. The colostrum corpuscle is characteristic of

milk of this period, while the large proportion of serum-albumin and casein present is often sufficient to coagulate the milk on boiling.

König gives the following as a percentage composition of cow's colostrum milk:—Water 74·67, casein 4·04, albumin 13·6, fat 3·59, lactose 2·67, and salts 1·43.

After the colostrum stage, the milk of the cow gradually alters in quality. Up to the second month after delivery, the casein and fat are increased. From the tenth to the twenty-fourth month the casein diminishes, while the fat becomes less from the fifth to the twelfth. The lactose lessens during the first month, but increases during the eighth, ninth, and tenth months. The salts appear to increase up to the fifth month, after which they steadily diminish.

How far the age of the cow, or the number of calvings, influence the milk is but little understood. As a rule, cows are not allowed to calve before the third or fourth year, pregnancy lasting 284 days; colostrum is secreted for a short time before and after delivery, and then milk for 300 days. Fleischmann says that the quantities of milk after the several births increase from 1550 litres at the first to 2400 at the sixth, decreasing then to 500 litres at the fourteenth. Aged cows undoubtedly give inferior milk, but that the mere number of pregnancies influence the composition of the milk is doubtful. The occurrence of the rut, during lactation, has no regular effect upon the milk; at times it is unchanged in quantity, but thin and poor, on other occasions it curdles on boiling even when fresh. Transient illnesses in the cow, such as diarrhœa or indigestion, act like defective feeding, often lowering the specific gravity of the milk four or five units.

The manner of milking materially affects the quality of milk. In the udders of a cow, a separation of cream takes place exactly as in a vessel. On this account, the milk first drawn, or "fore-milk," is always poor in fat, while the last portions, or "strippings," are rich in fat. Hence it follows that a good average milk can be obtained only if the udder is entirely emptied, and the whole milk well mixed. The first three strokes of a milking should not be collected, but should serve to rinse out the excretory ducts and remove any impurities or microbes which have entered. The time of milking has no distinct influence upon the quality of the milk, so long as it is performed at exactly equal intervals. If cows are milked at unequal intervals, the quantity of milk after the shorter intervals is smaller, but contains a higher precentage of fats and of solids. Small differences may be produced by a change of locality and an unaccustomed milker.

No exact statements can be made as to the composition of cream, as it varies so very considerably. From a very large number of analyses, the fat may be said to average from 45 to 49 per cent. The cream rises in from four to eight hours; it is hastened by warming the milk, but its quantity is not increased. The centrifugal apparatus now in use removes all, or nearly all, the cream in a few minutes. Cream so obtained commonly contains more fat than cream which has been obtained by allowing the milk to stand.

Milk alters in standing; it absorbs oxygen, and gives off carbon dioxide; placed in contact with a volume of air equal to its own bulk, it absorbs all the oxygen in three or four days. Subsequently lactic acid is formed in large quantities from the lactose; the milk becomes turbid, and finally casein is deposited. The cream which had previously risen to the surface in part disappears.

Milk in Relation to Disease.—That milk, after standing some time, turns sour and coagulates under bacterial action, is a fact familiar to all. Such sour milk is a fruitful source of digestive troubles in young children,

causing vomiting, flatulence, and diarrhœa. By similar action of bacteria, various coloured, stringy, or ropy milks are produced, all of which cause irritation of the intestine, producing diarrhœa, as well as in some cases giving rise to aphthous affections of the mouth in children. Besides these alterations in milk, which occur after it has been drawn, there are others which appear to be present in the milk when it is drawn.

It is well known that in human beings, bitters and purgatives, if taken by the mother, act upon infants taking the milk. In the same way, the milk of goats which have eaten colchicum or other Euphorbiaceous plants produces poisonous symptoms, including diarrhœa ; also in the case of cows affected with "trembles" due to eating the *Rhus toxicodendron*, their milk gives rise to vomiting and constipation.

The milk of cows affected with various forms of *mastitis* tends soon to decompose ; it may contain colostrum cells, or amorphous granules, pus cells, or epithelium, and occasionally blood. It then soon becomes acid, and the microscope usually detects abnormal cell forms and casts of the lacteal tubes.

How far the milk yielded by these inflamed mammary glands of the cow is capable of producing disease in the human being is not clearly defined, but there can be no doubt that such milk is unsuited for dietetic purposes.

There has been much discussion whether the milk from cows having foot-and-mouth disease can cause affections of the mouth, or give rise in human beings to any disease similar to that of cattle. Pigs can certainly get the disease from the milk of the cow. In men the evidence is discordant, and in a great measure negative ; still there are some striking cases, which seem sufficient to prove that an aphthous ulceration of the mouth may follow the ingestion of milk from cows suffering from foot-and-mouth disease.

Tuberculosis.—This disease is notoriously prevalent among bovines, and there is precise evidence to show that it can be transmitted by means of milk from the cow to other animals and to man. The Royal Commission on Tuberculosis make the following statement :—* "A very considerable amount of disease and loss of life, especially among the young, must be attributed to the consumption of cow's milk containing tubercle bacilli. The presence of tubercle bacilli in cow's milk can be detected, though with some difficulty, if the proper means be adopted, and such milk ought never to be used as food. There is far less difficulty in recognising clinically that a cow is distinctly suffering from tuberculosis, in which case she may be yielding tuberculous milk. The milk coming from such a cow ought not to form part of human food, and indeed ought not to be used as food at all." Newman gives the following percentage, of tubercular samples of milk found by various investigators under varying conditions as to time and place :—Berlin, 1898, 14 per cent. ; St. Petersburg, 1893, 5 per cent. ; London, 1901, 7 per cent. ; Islington, 1903, 14·4 per cent. ; Croydon, 1901, 6·7 per cent. ; Manchester, 1901, 9·5 per cent. ; Woolwich, 1902, 10 per cent. ; Liverpool, 1902, 8·7 per cent. ; Camberwell, 1902, 11 per cent. The application of the tuberculin test to all milch cows and the elimination of all suffering from tubercle appears to be the obvious and only remedy.

Zymotic Diseases.—Milk may also be a means of conveying the poisons of scarlet fever, of diphtheria, of enteric fever, and of cholera. The scarlet fever and diphtheria poisons have probably reached the milk from the cuticle or throat discharges of persons affected with those diseases, who were employed in the dairy while ill or convalescent. But the investigations by

* Second Interim Report, Part I., 1907, pp. 36 and 37.

Power and Klein, in connection with the Hendon outbreak, seem to show that cows are liable to a disease which, although comparatively mild as regards the animal itself, is capable of communicating scarlatina to man. Klein has shown that the *micrococci* found in such milk are probably identical with those found in scarlatina, and that they may be capable of exciting the disease in animals. There seem also grounds for believing that milk may be the means of transmitting diphtheria and certain forms of infective sore-throat from diseased cows, apart from direct contamination from human beings.*

That milk is not only a probable but an actual agent in the dissemination of enteric fever has long been recognised. This may occur either by adulteration of the milk with impure water containing the specific microbe, or by the use of similarly befouled water in washing out the milk vessels; or even from the milking of the cows by a person whose hands have been soiled by enteric dejecta. The facts as to the possibility of the dissemination of cholera by milk are similar. In tropical countries, where water buffaloes are a common source of milk-supply, diseases such as enteric fever, dysentery and cholera may be disseminated by means of milk drawn from cows which have recently wallowed, as is their wont, in filthy ponds, tanks or other surface waters, their udders dripping with what is often little better than sewage; this material falling into the can or vessel receiving the milk constitutes a ready means of infection. Recent work on the etiology of Malta Fever indicates that the milk of goats is the probable means by which the disease is disseminated. Some 50 per cent. of those animals in Malta appear to suffer from this affection, and 10 per cent. yield a milk which contains numbers of the specific micrococcus of this disease.†

Milk Epidemics.—Power has shown that outbreaks of disease transmitted by milk have the following characteristics:—

1. The outbreak is usually sudden, and the cessation is also abrupt, if allowance is made for late cases which have probably been infected from the earlier cases and not by the milk.

2. A large proportion of the attacks are simultaneous; the outbreak also reaches its maximum too rapidly to admit the possibility of infection from the first cases.

3. Two or more persons in the same house are taken ill at the same time. This may occur apart from milk infection, but it is very exceptional as regards the first invasion of the household.

4. The average number of cases per infected household is usually greater than occurs under ordinary conditions, but this depends on the number of persons who consume the milk. An *average* of two attacks per house may be considered high.

5. A very large proportion of the households attacked will be found to have a common milk-supply, which, however, may not be distributed by the same retailer.

6. If the number of households supplied by the suspected dairy be ascertained, and also the number of households attacked, it will be found that the proportion of the latter to the former is much greater than the proportion which the total number of infected households bears to the total number of inhabited houses in the district.

7. If the households be classified according to the amount of milk con-

* An instructive case of this kind is recorded by Chalmers, *Public Health*, September 1904, p. 769; also another by Robertson, *Public Health*, January 1905, p. 246. *See also* a paper by Savage, on an "Outbreak of Sore-throat at Colchester due to Infected Milk," *Public Health*, 1905.

† See *Journal Royal Army Medical Corps*, 1906, vol. vi. p. 627.

sumed daily, it will be found that the attacks are more numerous amongst households consuming a larger supply. The wealthier consumers generally suffer more than the poorer classes in milk epidemics.

8. Attacks are rare among persons who drink little or no milk, or only take it in tea or coffee, or always have it boiled.

9. As a rule there will be found a much heavier incidence among women and children. This will be epecially significant in outbreaks of enteric fever, which usually attacks young adults.

10. As regards scarlet fever, the type of disease is usually mild, and attended with a low mortality.

11. Cream, or milk kept over-night, is often more virulent than milk consumed in the fresh state.

Vaughan of Michigan has demonstrated, in old and stale milk, the presence of a ptomaine-like body which is toxic to animals. It appears to be found in marked quantity in cheeses and ice-creams, and is probably the cause of many of the cases of poisoning by those articles which are on record. Other cases are known in which milk, stored in dirty pans and in unwholesome or filthy surroundings, has given rise to most alarming symptoms. What are the precise changes induced in milk by these conditions is not well understood, but the probable decomposition is a transformation of the proteins into highly poisonous benzene derivatives, the most important of which is diazobenzene, commonly known as tyrotoxicon.

The Preservation of Milk.—The sterilisation of milk is a difficult process, because milk is particularly liable to infection by very hardy germs. The milk issuing from the udder of a healthy cow is already infested by bacteria. When milking is ended a small quantity of milk is left in the lacteal ducts, which become invaded by bacteria which make their way from the outside, and, favoured by the body temperature, undergo considerable multiplication. During the next milking these bacteria pass into the milk. In addition, the udder of the cow and the air of the cow-house are usually laden with bacteria, which also gain admission to the milk. The germ content of freshly drawn milk increases very rapidly during transport to the centres of consumption and also during storage in milk-shops.

Undoubtedly cleanliness plays a great part in securing a high keeping property for milk, but probably maintenance at a low temperature is of more importance. In milk kept at 95° F. the most rapidly developing micro-organism is the undesirable *B. lactis aerogenes* ; at a temperature of 70° F. this species develops relatively less rapidly than *B. lactis acidi*, which latter is very desirable for both cream and cheese ripening. At 50° F. the bacteria in milk increase slowly, and later consist of very few lactic organisms, but of miscellaneous types, including many that render milk unwholesome. These bacteria continue to grow slowly day by day, but the milk keeps sweet because the lactic organisms do not develop abundantly. Such milk in the course of time becomes far more unwholesome than sour milk, since it is filled with micro-organisms that tend to produce putrefaction. Although the temperature of 50° F. is to be recommended to the dairyman for the purpose of keeping his milk sweet, he must be on his guard against thinking that milk which is several days old is proper for the market ; old milk is never wholesome, even though it has been kept at 50° F. and remains sweet and uncurdled.*

Experience teaches that a short exposure to a temperature of 158° F. or 70° C. destroys most of the pathogenic organisms in milk and all the bacilli

* Conn: *Dairy Bacteriology*, Bulletin No. 25, United States Department of Agriculture, 1895; also see *Bacteriology of Milk*, by Swithinbank and Newman, London, 1903.

to which the ordinary souring is due. Consequently it has been suggested to *pasteurise* milk, viz., raise it to a temperature of 75° C. or 167° F. for half an hour; this process gives all the advantages mentioned without any appreciable deterioration of the nutritive qualities of the milk. Of this method, however, it may be said that it fails to destroy spore-bearing organisms, and certainly does not kill some bacteria capable of causing diarrhœa. Further, milk so treated will not keep more than three days, as some putrefactive bacteria are still present, also there is difficulty in avoiding alterations in taste. To completely sterilise milk it is necessary to either expose it to a temperature of 100° C., on several successive days, or raise it to 120° C. for fifteen minutes. Sterilisation is undoubtedly the most efficient way of dealing with germs in milk, but it is not without drawbacks. It alters the taste, destroys the fine emulsification of the fat, coagulates the lactalbumin and renders the casein less easy of digestion.

Recently, two interesting methods for the preservation of milk have been introduced. In one, peroxide of hydrogen is added to the milk and the mixture heated to 51° C. for three hours. This heat, coupled with the action of the enzyme catalase present in the milk, decomposes the peroxide with the liberation of nascent oxygen, which acts as an efficient germicide. Milk so treated is normal in taste and keeps fresh for eight days in hot weather. The amount of peroxide required to obtain this result is 15 c.c. of a 3 per cent. solution per litre.* The other process consists in drying milk by passing it in a thin layer between two heated rollers in such a way that it is immediately desiccated and reduced to a fine powder, which merely requires the addition of water to bring it back to the condition of ordinary milk. The powder so prepared appears to contain all the solids of the original milk in a sterile and soluble form, and so far as our experience goes is of the highest nutritive value.† If manufactured carelessly, it is conceivable, however, that such dried milk may be devitalised, and lacking antiscorbutic properties be an unsuitable food for infants.

The preservation of milk is also attained by adding antiseptics, such as salicylic acid, boric acid, and formalin, to the milk, either before or after it has been heated. The common forms, however, of preserved milk are the concentrated ones, such as the dried milk, and the so-called condensed milks with or without sugar. Those without sugar keep less well than those with sugar, once the tin in which they are sold is opened. The majority of condensed milks are made by evaporating down the original milk to a third or a quarter, and then adding sugar to it; this added sugar tends to make condensed milks rather fattening; but their nutritive value is often below that of the fresh article, simply because many of the so-called condensed milks in the market are nothing more than condensed separated milks (that is, milks from which nearly the whole of the cream has been mechanically separated) mixed with sugar, and really contain a very low percentage of fat—so low as to be negligible quantities so far as value to the consumer is concerned. Of course there are notable exceptions to this rule; such condensed milks being actually condensed whole milks as distinguished from the comparatively worthless condensed separated milks. A clear understanding upon this subject is very necessary in the interests of the feeding of infants. "Milk" at no time should be construed so as to mean "thinned milk," nor does it mean "separated milk." These, which are, as every one knows, articles of commerce, should be described at all

* See *Public Health*, January 1905, p. 251; *also* October 1905, p. 40.

† Hewlett: "On the Budde Process for the Preservation of Milk," *Lancet*, January 27, 1906.

times by their distinctive titles. Condensed milk means condensed whole milk, and if a preparation which has been obtained by condensing separated milk is called condensed milk, its sale as such amounts to a distinct fraud upon the public.

Condensed or preserved milks, prepared entirely from skimmed milk, are found on analysis to show an average of only 0·72 per cent. of fat. Some brands, prepared from partly skimmed milk, or from skimmed milk to which a small proportion of unskimmed milk has been added, show an average of 3·14 per cent. of fat.

From a nutritive point of view, the chief defect of condensed milks is that they are apt to contain too little fat; the unsweetened condensed whole milks are alone satisfactory in this respect. The sweetened whole milks require so great a dilution, owing to the excess of sugar, that the product is notably deficient in fat.

	Protein.	Fat.	Milk-sugar.	Cane-sugar.	Salts.	Alcohol.	Lactic Acid.
Ideal	8·3	12·4	16·0	—	—	—	—
Viking	9·0	10·0	13·3	—	—	—	—
Hollandia	11·3	9·8	18·5	—	—	—	—
First Swiss	9·7	10·5	14·2	—	—	—	—
Rose	8·3	12·4	17·6	36·1	—	—	—
Milkmaid	9·7	11·0	14·6	38·7	—	—	—
Nestlé	9·7	13·7	15·0	37·2	—	—	—
Anglo-Swiss	8·8	10·8	16·0	37·1	—	—	—
Full-weight	12·3	11·0	13·5	37·2	—	—	—
Kéfir	3·1	2·0	1·6	—	0·8	2·1	0·8
Koumiss	2·2	2·1	1·5	—	0·9	1·7	0·9

The anomalous state of the law which has hitherto permitted condensed milk which has been deprived of its fat to be sold as "condensed milk," has been rectified by the passage of the Sale of Food and Drugs Act, 1899, which imposes a penalty on any person who shall sell or offer for sale adulterated or impoverished milk or cream, except the same is made up in packages or tins conspicuously marked and indicating that the milk or cream has been so treated.

Strictly speaking, both "Koumiss" and "Kéfir," which are fermented milks of the mare and cow respectively, are forms of preserved milk, both containing lactic and carbonic acids, with some alcohol. In Kéfir the casein is partially changed into albumose and peptone. Both these forms of fermented and partially digested milk are used as food for the sick, or those in whom digestion is feeble. The percentage composition of some preserved milks is given in the foregoing table.

EXAMINATION OF MILK.

Although the milk from individual cows varies largely in composition, yet the mixing of the milk given by a herd averages the general composition within certain limits. The examination of a milk sample is intended primarily to determine whether it is what it is said to be—that it is pure and wholesome; and that it has not been adulterated or sophisticated so as to be, in any way, detrimental to health. The chief adulterations of milk are :—

1. The addition of water (not necessarily pure water).
2. Removal of part of the cream and adding water to bring the specific

gravity to the normal; or removal of the cream from the evening milk and adding the morning milk.

3. The addition of starch, flour, gum, dextrin, or glycerin.

4. The addition of bicarbonate of soda, borax, boric and salicylic acid and formalin as preservatives.

In the examination of a milk sample, attention should be directed to the following preliminary observations:—

The Physical Characters.—Placed in a narrow glass, the milk should be quite opaque, of full white colour, without deposit, and without peculiar smell or taste. When boiled it should not change in appearance.

Reaction.—Reaction should be slightly acid or neutral, or very feebly alkaline; if strongly alkaline, either the cow is in ill-health or there is much colostrum; or sodium carbonate has been added. Milk, when just drawn from the cow, is sometimes both acid and alkaline; that is, it turns blue litmus red, and turmeric brown, giving what is known as the "amphioteric" reaction. This is probably due to the presence of acid phosphates of the alkalies. Strong acidity means the presence of lactic or butyric acid, and is indicative of retrograde changes in the milk.

The Cream.—When milk is allowed to stand, some of the fat rises gradually, and forms a rich layer, constituting cream. Its proportion depends on several conditions, and can be readily determined in the following way. Put some of the milk in a long glass, which is graduated to 100 parts; a 100-centimetre or litre measure will do, or a glass may be specially prepared by graduating a hundred equal spaces on a strip of paper, and gumming it on the glass. Allow it to stand for twenty-four hours in a cupboard secured from currents of air. By this means the percentage of cream can be seen, and the presence of deposit, if any, observed. There should be no deposit till the milk decomposes; if there be, it is probably chalk or starch.

The cream should be from $\frac{6}{100}$ths to $\frac{11}{100}$ths; it is generally about $\frac{8}{100}$ths; in the milk of Alderney cows it will reach $\frac{30}{100}$ths or $\frac{40}{100}$ths. The time of year (as influencing pasture), and the breed, should be considered.

Unfortunately the amount of cream formed in a given time cannot be taken as a measure of the richness of the milk. Water added to milk causes a more rapid separation of the cream, and milk subjected to centrifugal action yields a much larger percentage of cream, practically all the fat being removed.

For the detection of the more common adulterations of milk, namely, the removal of cream and addition of water or other matters, recourse must be made to the following determinations:—

Specific Gravity.—In all milks the specific gravity is understood to be taken at 15° C. or 60° F. The instrument usually employed is a lactometer. The specific gravity of normal milk varies between 1·027 and 1·034, being less in proportion as the fat is greater. A milk the specific gravity of which has been raised by removal of fat (skimming), can be restored to its original specific gravity by adding water, so that this determination by itself cannot be taken as a reliable index of the character of a sample. But taken in conjunction with the figures for total solids or for fat, it is of the greatest value, and constitutes a reliable check upon other determinations.

Expressed in general terms, it may be said that the specific gravity of milk falls 1 degree for each rise of 10° F. above 60° F., and that, at that temperature, there is a loss of 3 degrees of gravity for every 10 per cent. of water added.

Owing to the fact that milk, especially when first drawn, often contains bubbles of air, care must be taken in mixing the samples before taking the

density, and to allow sufficient time for the escape of any bubbles that may be present.

Total Solids.—Evaporate a known quantity, say 2 c.c., of the milk to dryness in a flat and shallow dish, and weigh. Calculate out as a percentage. The heat employed should not exceed 100° C. (212° F.) and should be continued for at least three hours, taking care that there is no charring. The specific gravity of the milk being known, the amount taken can be readily calculated. Thus, 2 c.c. of milk, whose specific gravity is 1·032, would weigh 2·064 grammes, and if after evaporation this amount of milk gave a solid residue of 0·284 gramme, the percentage of total solids yielded by the sample would be $\frac{0{\cdot}284 \times 100}{2{\cdot}064} = 13{\cdot}76$. The total solids found ought not to be below 11·5, but more usually average between 12 and 13 per cent.

Ash.—The residue or dried solids, in the last determination, may be incinerated, re-weighed, and calculated out in a similar manner as so much ash. In normal milks this averages about 0·73 per cent., and in no case should fall below 0·7; if the milk be watered, it will be less. Any marked degree of alkalinity or effervescence of the ash with hydrochloric acid will suggest the addition of a carbonate.

Fat.—The estimation of the fats constitutes a very important determination. This is best done by means of the apparatus of Gerber or of Soxhlet, in which ether is made to pass repeatedly through the solids of milk. Adams' process is largely employed for the determination of fat. It is performed as follows:—

Thoroughly shake up the sample and fill a 10 c.c. burette with it. Next prepare a helical coil by rolling a strip of fat-free paper 2½ inches wide and 22 inches long, previously threaded with string or wire down the centre; the ends of the string or wire are fastened outside the coil. The milk is then allowed to enter the coil from a burette, and the number of c.c. used, taken in conjunction with the specific gravity of the sample, enables the weight of milk operated on to be calculated, or the coil may be placed in a beaker containing a known weight of milk, and after the coil has been removed a re-weighing of the beaker will give the amount of milk absorbed by the paper. The coil is next dried in the air or an oven for two hours, and then introduced into the Soxhlet apparatus. The dried and weighed bottle is then filled two-thirds full with ether and attached to the apparatus, and the fat extracted by about twelve siphonings. The ether is then evaporated off in a hot-water bath, and the bottle finally dried in the hot-air bath at 212° F., allowed to cool, and then weighed. The gain in weight gives the amount of fat contained in the weight of milk used in the experiment.

In Gerber's method, 2 c.c. of the milk mixed with plaster of Paris are dried on a porcelain lid and the dried solids are then scraped off and placed in a funnel of fat-free paper, which is placed in the glass funnel of the Gerber apparatus. All traces of solids are removed from the porcelain lid by washing with ether; the washings are filtered through the filter-paper, and the bottle (previously dried and weighed) then filled about half full with ether. By heating the bottle in a water-bath at a temperature of about 150 F., the ether volatilises and passes through the solids, and being recondensed above, falls back into the bottle through the filter-paper. In this way the solids are constantly washed with ether for about two hours. The bottle is then detached, the ether being evaporated off as before; the bottle is dried, cooled, and weighed. The gain in weight gives the amount

of fat in the number of c.c. of milk placed on the lid, and the specific gravity of the milk being known, the percentage of fat by weight is easily calculated. Should the milk have become sour, Adams recommends the addition of ammonia, which restores the fluidity without otherwise affecting the constituents.

What is known as the Werner-Schmidt method is a fairly satisfactory means for the determination of fat, and is especially suitable for sour milk. Measure 10 c.c. of the milk into a long test-tube of 50 c.c. capacity, graduated to tenths of a c.c., and add 10 c.c. of strong hydrochloric acid. After mixing, the liquid is heated for one minute until it turns a brown colour. The tube and contents are cooled in water, ether added up to the 50 c.c. mark, and the cork inserted. The tube is then well shaken and set aside until the ether has separated. At the junction of the brown mixture of hydrochloric acid and milk and the ethereal solution a fluffy layer of casein appears. The number of c.c. occupied by the ether plus $\frac{3}{4}$ths of the fluffy layer of casein are read off and noted, as they contain all the fat which was present in the 10 c.c. of milk operated on. The cork is removed and half of the clear ether then pipetted off into a weighed platinum capsule, the ether is evaporated, the capsule dried, cooled and weighed as in the other processes. The gain in weight gives the amount of fat in 5 c.c. of milk of known specific gravity, so the percentage by weight is easily calculated.

Leffmann and Beam have devised a method for determining the amount of fat by means of a centrifugal apparatus. The procedure is as follows:—15 c.c. of the milk to be examined are run into a test-bottle which has a capacity of about 30 c.c. and is provided with a graduated neck, each division representing $\frac{1}{10}$th per cent. by weight of butter fat; 3 c.c. of a mixture of equal parts of amylic alcohol and strong hydrochloric acid are now added and thoroughly mixed with the milk; then 9 c.c. of pure sulphuric acid are added slowly, about 1 cubic centimetre at a time, and the contents of the bottle shaken carefully. The milk will assume gradually a chocolate colour passing to a deep brown with the generation of much heat. When the whole of the 9 c.c. of acid has been added, the contents of the tube or bottle must be filled up to the zero mark with a hot and freshly made mixture of one part of strong sulphuric acid with two of water. The bottle should be placed in one of the carriers of the machine and whirled for at least two minutes. If only one sample of milk is being tested, the opposite carrier must be balanced by a corresponding bottle filled with dilute sulphuric acid. A milk poor in fat may need centrifugalising for four or five minutes, but usually two minutes is enough; very rapid rotation in not necessary. On stopping the centrifugaliser and taking the bottle out of the carrier, the fat will be seen to have separated out as a layer on the top, and the percentage in the sample is readily read off. This method is subject to an error of about 0·1 per cent., but its rapidity and ease render it a valuable and reliable means of fat determination.

Several investigators have, from time to time, proposed formulæ by which, when any two of the data, specific gravity, fat, and total solids, are known, the third can be calculated. At times these formulæ are very serviceable. That of Hehner and Richmond is the best, and is now very extensively used, being based on an extensive range of observation and perfect processes of fat extraction. The formula is as follows:—

$F = 0{\cdot}859\ T - 0{\cdot}2186\ G$, in which F is the fat, T the total solids, and G is the specific gravity. This formula does well for ordinary milks, but in the case of poor skim milks, it has been found necessary to modify it as follows:—

$$F = 0{\cdot}859\,T - 0{\cdot}2186\,G - 0{\cdot}05\left(\frac{G}{T} - 2{\cdot}5\right).$$

This correction is only to be applied when G, divided by T, exceeds 2·5. In these formulæ, G represents the last two units of the specific gravity and any decimal. Thus, if the observed gravity be 1029·7, G will be 29·7.

A ready means of applying this formula is afforded by the use of Richmond's slide rule. This has three scales, two of which, for total solids and fat respectively, are marked on the body of the rule, while that for the specific gravity is placed on the sliding portion. The divisions of the scales are arranged as follows :—On the total solids scale, 1 inch is divided into tenths ; on the fat scale, 1·164 inch is divided into tenths ; while on the specific gravity scale, 0·254 inch is divided into halves. To use the rule, adjust the figure of the observed specific gravity to that of the total solids found, when the arrow point will indicate the percentage of fat ; or, if the fat be known, then by adjusting the arrow point to the graduation corresponding to the fat found, the figure for the specific gravity will coincide with that for the total solids. This slide rule does not allow for the correction for poor skim milks, but the error from this cause does not exceed 0·08 per cent., and may be practically disregarded.

For cases in which the fat and specific gravity are known, Richmond has proposed the following new formula for calculating the total solids :— $T = 1{\cdot}2\,F + 0{\cdot}14 + 0{\cdot}25\,G$.

Casein.—Take a weighed or measured quantity of milk ; add two or three drops of acetic acid and boil. Add an excess of water ; allow to stand for twenty-four hours ; pour off the supernatant fluid ; wash the precipitate well with ether at 80° F. ; dry and weigh. Calculate the percentage as casein ; it is difficult to free it entirely from fat. Wanklyn recommends the albuminoid ammonia process, as in the case of nitrogenous matter in water, one part of casein yielding 0·065 of ammonia. This determination is not often required.

The serum-albumin may be estimated in the whey after clotting a measured quantity of milk by rennet. A measured amount of the filtered whey is precipitated by excess of alcohol, the precipitate collected, washed with ether and alcohol, dried and weighed.

Lactose may be determined either by means of a saccharometer, or by a standard solution of copper.

Of the various kinds of saccharometer, the so-called half-shadow instruments are the most satisfactory. They are so arranged, by the use of a semicircle of thin quartz, that the field is divided into semicircles which are equally illuminated when the instrument registers zero. On the introduction of a tube carrying the sugar solution, the illumination becomes unequal, and the angular rotation of the analyser which is required to restore the original condition, measures the rotation which has been caused by the sugar.

In the various transition tint saccharometers, as well as in Schmidt and Haensch's latest form of half-shadow instrument, the graduated scale does not directly give measurements in angular degrees, but expresses a percentage of sugar directly in terms of cane-sugar.

In the Soleil-Duboscq saccharometer the scale is so constructed that the 100 point is recorded by a solution of cane-sugar in a 200 mm. tube containing 16·35 grammes of pure cane-sugar per 100 c.c. ; consequently, each degree of the scale represents 0·1635 gramme of cane-sugar per 100 c.c.

In the Soleil-Ventzke-Scheibler saccharometer, and in Schmidt and Haensch's modification of it, the scale is so constructed that the 100 point is recorded by a solution in a 200 mm. tube containing 26·048 grammes of

pure cane-sugar per 100 c.c.; consequently, each division of the scales on these instruments represents 0·26048 gramme of cane-sugar per 100 c.c.

In order to facilitate calculations of percentages of various sugars by those using either a Soleil-Ventzke-Scheibler, or Schmidt and Haensch's saccharometer, the following factors may be used, and by which scale divisions on those instruments may be multiplied, to obtain percentage statements of the particular sugars being examined :—

Kind of Sugar.	Saccharometer Factor.
Dextrin	0·0866
Cane-sugar	0·2604
Maltose	0·1240
Dextrose	0·3258
Lactose	0·3126
Lævulose	0·1805
Invert-sugar	0·8094

Before the estimation of lactose can be made in milk by means of the polarimeter or saccharometer, certain proteins which are always present in milk, and which possess a left-handed rotation, must be removed as well as the fat. The most reliable method for ensuring this appears to be that recommended by Wiley, which is as follows :—

The sp. gr. of the milk is first determined; if this should be 1026 or thereabouts, 60·5 c.c. of the milk are transferred to a 100 c.c. flask and 1 c.c. of mercuric nitrate solution, or 30 c.c. of mercuric iodide solution (preferably the latter), added. The liquid in the flask is then made up to 102·4 c.c. with distilled water, well shaken, filtered bright, and polarised in the 200 mm. tube of the saccharometer.

The volume is made up to 102·4 c.c., because the precipitated albumin occupies a volume of about 2·4 c.c., so that the solution is really diluted to 100 c.c. Should the sp. gr. of the milk be 1030, 60 c.c. are taken instead of 60·5 c.c., and if the sp. gr. be 1034, 59·5 c.c. are taken.

The room and milk should be at one constant temperature, and the polarisation taken at the same, about 15° C. being the best suited for the purpose, although a few degrees above or below will not appreciably affect the results.

In the absence of mercuric nitrate or iodide solution, the proteins may be precipitated from the milk by means of acetic acid and heat as subsequently explained in the copper process for the estimation of lactose. Acetic acid is less preferable, as it often fails to remove all the albumins. The mercuric solutions are prepared as follows :—Mercuric nitrate by dissolving mercury in double its weight of nitric acid (sp. gr. 1·42), then adding to the solution an equal volume of water. One c.c. of this re-agent is sufficient to precipitate the proteins in 50 to 60 c.c. of milk. The mercuric iodide solution is made by taking potassium iodide 33·2 grammes, mercuric chloride 13·5 grammes, acetic acid (sp. gr. 1·04) 20 c.c., and water 640 c.c. Of this solution 30 c.c. are required for 50 to 60 c.c. of milk.

The presence of mercury in the filtrate (whey) when these re-agents are used is objectionable, as the filtrate can only be used for the single purpose of polarimetrical observations.

To determine the lactose by the copper solution, we require a standard solution to be made by taking 34·64 grammes of pure copper sulphate and dissolving in 200 c.c. of distilled water. Take also 173 grammes of tartrate of sodium and potassium and dissolve in 480 c.c. of solution of caustic soda

or potash. Mix the two solutions slowly, and dilute with distilled water to one litre. One c.c. of this solution is reduced by 5 milligrammes of either glucose or invert-sugar, and by 6·67 milligrammes of lactose.

To estimate the milk-sugar by means of this solution, place 10 c.c. of milk in a test-tube, add a few drops of acetic acid, and warm—this coagulates the casein with the fat; pour into a Nessler glass, wash out all the curd from the test-tube with distilled water; then make up to 100 c.c. with distilled water, break up the curd thoroughly with a glass rod, filter through four filter-papers, and put the filtered whey (which ought to be as clear as possible) into a burette. Take 10 c.c. of standard copper solution, put it in a porcelain dish, and add 50 to 80 c.c. of distilled water; boil; as soon as it is in brisk ebullition drop in the whey from the burette; take care that the liquid is boiling all the time; continue the process until the copper is all reduced to red suboxide and no blue colour remains in the supernatant liquid; but stop before any yellow colour appears. Read off the amount of whey used, and divide by 10; the result is the amount of milk which exactly decomposes 10 c.c. of the copper solution. The 10 c.c. of the copper solution are equal to 0·0667 gramme of lactose. The amount of lactose in the 10 c.c. of milk is then known by a simple rule of three; and the amount in 100 c.c. of milk is at once obtained by shifting the decimal point one figure to the right.

Example.—15 c.c. of diluted whey were required to reduce the 10 c.c. of copper solution, $\frac{15}{10} = 1{\cdot}5$, the amount of original milk which had a sp. gr. of 1030; $0{\cdot}0667 \div 1{\cdot}5 = 0{\cdot}0445$ gramme of lactose in 1·030 gramme of milk; therefore $\frac{0{\cdot}0445 \times 100}{1{\cdot}030} = 4{\cdot}32$ per cent.

Microscopic and Bacteriological Examination of Milk.—It is always advisable to examine a milk sample microscopically. The only strictly normal constituents of milk are the round oil globules of various sizes in an envelope and a little epithelium. The abnormal constituents are epithelium in large amount, pus, conglomerate masses, and casts of the lacteal tubules. The added ingredients may be starch grains, portions of seeds, and chalk (round and often highly refracting bodies, with often a marked double outline, at once disappearing in acid). Colostrum, occurring for from three to eight days after the birth of the calf, is composed of agglomerations of fat vesicles united by a granular matter.

Milk from a healthy cow is secreted free from microbes; but micro-organisms always find their way into the milk from the surface of the udder, from the hands of the milker, from particles of dung, from the milk cans, or from the air of the cowsheds. The average number of micro-organisms found in samples of milk by us is not less than 400,000 per cubic centimetre. Other observers have given the number found in other milk-supplies at an even higher figure, but it must be remembered that in any numerical examination the sources of error are very numerous. Owing to its peculiar composition, milk always constitutes a favourable medium for various forms of microbes, which multiply rapidly in it if the milk is not at once exposed to very low temperatures. Repeated examinations have shown that the residues of milk in the excretory ducts of the udder are frequently rich in bacterial life, and that it is the earlier portions of milk drawn off at a milking which are the most common source of infection; for this reason, they should as a rule be rejected. It has been suggested to centrifugalise the milk as an aid to the detection of the contained bacteria. Scheurlen found that of the ordinary bacteria, and also anthrax, typhoid, and cholera organisms, three-fourths went into the cream on being centrifugalised, and the rest

remained in the separated milk. Tubercle bacilli, however, were to a large extent ejected, only a few organisms being found in the cream and separated milk. The method of examination of milk is that customary for other liquids. Cover-glass preparations are readily prepared by placing the smeared and dried cover-glasses in a small capsule containing 5 c.c. of chloroform and 1 c.c of a saturated alcoholic solution of methylene blue. After five minutes, the chloroform is evaporated, the glasses rinsed in water and examined in the usual manner.

Examination of the milk by cultivation is more important; on account of the great number of micro-organisms usually present, free dilution is necessary; of culture media, agar is perhaps the best for milk. Any numerical estimation of bacteria can only be of scientific value when making a series of comparative examinations under similar conditions of the same milk-supply or when checking the efficiency of filtration, pasteurisation or sterilisation. To determine the kinds of bacteria in a milk sample is an almost hopeless task, but an endeavour should be made to detect if possible the presence of such organisms as the *B. coli*, the *B. enteritidis* of Gärtner, the *B. tuberculosis*, the *B. enteritidis sporogenes* and the *B. diphtheriæ*. Probably animal inoculation is the only reliable test as to virulence, especially in regard to the tubercle and Gärtner bacilli. Supplementary to any purely bacterial examination is the determination of the presence or absence of organic cells foreign to clean milk and the quantity and nature of general dirt or particulate matter other than milk constituents.

Milk drawn from diseased cows may contain various pathogenic forms, especially the *bacilli of tuberculosis*, or cocci which produce suppuration. The detection of the tubercle bacillus in milk by direct culture therefrom is difficult; it is much more reliable to inject from 10 to 15 c.c. of the suspected milk, as fresh as possible, into the peritoneal cavity of a guinea-pig. After four weeks, the animal should be killed, when, if the bacilli have been present, there is found the characteristic appearance of peritoneal tuberculosis.

Newman has suggested the following bacteriological standards of purity for milk:—(*a*) the acidity of 100 c.c. of the sample *plus* 2 c.c. of a 0·1 per cent. solution of phenol-phthalein should not require more than 25 c.c. of deci-normal alkali to produce a permanent faint pink colour; (*b*) no excess of pus or blood-cells; (*c*) no *B. coli*, *B. enteritidis sporogenes* or *B. enteritidis* of Gärtner in 1 c.c.; (*d*) the milk to be non-virulent. It is conceivable that (*a*) and (*d*) might be made absolute standards, while (*b*) and (*c*) could be relative, necessitating further inquiry into the cow's environment. We certainly think the acidity test to be a valuable index of freshness.*

The facts regarding the general bacterial impurity of milk samples suggest the urgent need of reforms in connection with both the milking of cows and of the sale of milk generally. The following suggestions have been formulated by a special commissioner of the British Medical Association, when reporting on the milk-supply of London. They are sufficiently to the point to merit adoption, not only in the metropolis but elsewhere.

1. "That all milking be carried on in the open air, the animals and operators standing on a material which is capable of being thoroughly washed, such as a floor of concrete or cement. Such a floor could be easily laid down in any convenient place which can be found. The site chosen should be

* Newman: "Bacteriological Examination of Milk," *Public Health*, December 1905, p. 157. *See also* Houston: "The Bacteriological Examination of Milk in Relation to Standards," being a Report to the London County Council, 1905.

removed from inhabited parts as far as possible, and should be provided with a plentiful water-supply."

2. "That greater care be expended on the personal cleanliness of the cows. The only too familiar picture of the animal's hind quarters, flanks and sides being thickly plastered with mud and fæces is one that should be common no longer. It would not be difficult to carry out this change; indeed, in the better managed of our large dairy companies' farms such a condition no longer prevails, but in the smaller farms it is but too frequently met with."

3. "That the hands of the milker be thoroughly washed before the operation of milking is commenced, and that after once being washed they be not again employed in handling the cow otherwise than in the necessary operation of milking. Any such handling should be succeeded by another washing in fresh water before again commencing to milk."

4. "That all milk-vendors' shops should be kept far cleaner than is often the case at present. That all milk-retailing shops should be compelled to provide proper storage accommodation, and that the counters, &c., should be tiled."

Formation of an Opinion as to Adulteration of Milk.—It has already been indicated that the favourite sophistications of milk consist, on the one hand, of the more or less complete removal of the cream, and, on the other, of the addition of water. If milk is deprived of a large part of its lightest constituent, the fat, it becomes specifically heavier, and a simple determination of its specific gravity reveals the fraud. But if to a milk which, in spite of its fat, is still heavier than water on account of its dissolved solids, water be added, its specific gravity will fall below the normal limits and thus betray the adulteration. It is, however, evident that simultaneous skimming and watering, if carried out under the guidance of the lactometer, may produce a spurious milk of the same specific gravity as the new or original milk.

"Experienced milk sophisticators, however, have other methods more difficult to detect than this crude one of mere dilution. The introduction of cream separators has given them the opportunity of removing very cheaply and quickly almost the whole of the fat from milk, dividing the milk, in fact, into a cream much better than what is produced by ordinary skimming, and a skim milk, beside which ordinary 'skim' is rich indeed."

"The sophisticator has thus the power of either separating his milk in a moderate degree, just taking from it what, from his point of view, is the 'excess' of cream; in other words, reducing its cream to the lowest saleable standard without exposing himself to any such risks of detection as would attend the process of 'watering,' a process by which the total non-fatty solids might be so reduced as to lead to detection of the fraud; or he may take off all the cream, using the 'skim' to dilute or standardise other fresh milk; or he may sell the 'skim,' and leaving it to the retailer to produce, by judicious mixture of his two churns, any quality of milk which the character of his district or the carelessness and indifference of his customers may appear to require; or, finally, he may use the skim milk for making cheese, substituting a sufficiency of some other form of fat for the cream he has abstracted."

If carried out judiciously, and kept within the limits imposed by the standard which the magistrates will accept, it is next to impossible to prove this form of sophistication, except one discover the source of the milk, and have an opportunity of milking the cows from which the suspected milk is stated to have been drawn. Given these circumstances, it is possible to be morally certain that a fraud has been committed.

Watering involves the risk that organisms pathogenic to man may pass into the milk with the water and probably multiply there. In comparison with watering and skimming all other methods of sophistication are rare in the present day, though, formerly, the addition of chalk, milk of lime, gum, starch, and sugar were not infrequent. As regards the removal of cream, an important distinction must be made between removal by a centrifugal separator and removal by skimming. The former method, beyond reducing the nutritive value of the milk, adds no further disadvantage, as the creaming is effected rapidly, and the milk remains fresh. The other method, or skimming, is slow, and not only deprives the milk of its cream, but also involves the changing of the liquid from the category of a fresh to that of a more or less sour milk.

Watering alone is detected by a lower specific gravity and a diminished quantity of cream. *Creaming* alone is detected by a heightened specific gravity and a diminished quantity of cream. When both are resorted to, the cream will be small in amount, but the specific gravity may be normal. When a quantitative analysis can be made, watering alone is indicated by a general lowering of the constituents, which, however, preserve their normal proportions to each other. Creaming alone is indicated by a lessened amount of fat, but a normal amount of everything else, except total solids. Creaming and watering may be known by a general lowering of all constituents, but the deficiency in fat will be most marked.

The decision as to the addition of water and the removal of cream from milk is notoriously difficult, chiefly owing to the want of knowledge as to what was the original composition of the milk from which the sample was taken. To meet this difficulty, and to prevent adulteration, many efforts have been made to establish a minimum for the composition of normal milk.

The Sale of Milk Regulations, 1901, made under section 4 of the Sale of Food and Drugs Act, 1899, lay down that (*a*) where a sample of milk contains less than 3 per cent. of milk fat it shall be presumed, until the contrary is proved, that the milk is not genuine by reason of the abstraction therefrom of fat or the addition thereto of water; (*b*) where a sample of milk contains less than 8·5 per cent. of "solids not fat," it shall be presumed, until the contrary is proved, that the milk is not genuine by reason of the abstraction therefrom of solids not fat or the addition thereto of water; and (*c*) when a sample of skimmed or separated milk (not being condensed milk) contains less than 9 per cent. of solids (including fat) it shall be presumed that the milk is not genuine. These regulations are in force throughout Great Britain.

Assuming that the "solids not fat" in a normal milk are never less than 8·5 per cent., and that a given sample has yielded 3·1 per cent. of fat and the total solids were 11·1 per cent.; obviously the solids not fat are 8 per cent. Then $\frac{8 \times 100}{8{\cdot}5} = 94{\cdot}1$ per cent. of the sample is pure milk, or nearly 6 per cent. of water has been added. In a similar way the observed amount of ash in a milk sample may be used as a standard, taking the ash of a normal milk to be never less than 0·7 per cent.

Cane-sugar.—This carbo-hydrate is not a common addition to milk, being only usually met with in samples of preserved and concentrated milks. The diagnosis of a milk adulterated with cane-sugar depends upon :—(1) Any considerable want of agreement between the results from the copper process and the polarimeter. (2) Any considerable rise in the amount of copper reduced, or any increase of rotating power after inversion of the sugar in the whey, by means of citric acid and heat, or by invertase, which re-agents

only affect the cane-sugar and not the lactose. (3) The separation and preparation of the osazone from the whey by means of sodic acetate and phenyl-hydrazin hydrochlorate. Lactosazone is alone obtained by treatment with phenyl-hydrazin ; cane-sugar giving no osazone until inverted, it then gives an osazone not to be distinguished from glucosazone. Lactosazone is freely soluble in hot alcohol, and none separates on cooling, unless the solution be highly concentrated. On the other hand, glucosazone requires repeated boiling in considerable quantities of absolute alcohol before it dissolves. Lactosazone is warty or starch-like in appearance, whereas glucosazone is always in the form of needle crystals.

Glycerin has been sometimes met with. The milk will be sweeter than usual, and there will be a difficulty if not impossibility in drying the solids by evaporation.

The commonest antiseptics added to milk as preservatives are boric acid or borax and formaldehyde, whilst salt, salicylic acid, the fluorides and sodium carbonate are occasionally employed. In our experience, boric acid, formaldehyde and salicylic acid are the most common, in the order named. A Departmental Committee appointed by the Board of Agriculture has suggested that no preservatives or colouring-matter be allowed in milk at all, but up to the present this recommendation has no legal value and cannot be enforced.

Boric Acid.—The amount added varies, but it averages from 3 to 8 grains per pint. For its detection, the following procedure may be used. Reduce 25 c.c. of the dried milk to an ash slowly in a capsule, add a few drops of hydrochloric acid, sufficient to render it distinctly acid, and then 25 c.c. of distilled water. Now dip strips of turmeric paper in the mixture and dry them over a flame. If boric acid be present the turmeric paper will turn a crimson red, which on the further addition of sodium carbonate becomes blue.

As a quantitative test the following is recommended by Thresh.* Take 100 c.c. of the milk in a long-necked flask, heat rapidly to the boiling-point, remove the flame and add 8 c.c. of a 2 per cent. nitric acid solution. Stopper and allow to cool. When cold, filter off 50 c.c., which, allowing for curd formation, represents virtually 50 c.c. of the original milk. Add a few drops of a 10 per cent. solution of calcium chloride and render faintly alkaline by the addition of sodium carbonate. Evaporate to dryness in a platinum dish and incinerate at a moderate temperature. Exhaust the ash with successive small quantities of boiling water and evaporate, if necessary, to 25 c.c. When cold, render neutral to methyl-orange, add 25 c.c. of glycerin, and titrate with deci-normal solution of soda until alkaline to phenol-phthalein. Each cubic centimetre of the deci-normal soda solution represents 3·5 mgm. of B_2O_3, 6·2 mgm. of H_3BO_3 or 9·55 mgm. of crystallised borax.

Formaldehyde.—Added to milk in the form of formalin (a 40 per cent. solution of formic aldehyde), this is a frequent preservative employed by dealers in milk. The amount added varies, but may be as much as 1 in 20,000, or as little as 1 in 120,000. As an average statement 1 part in 50,000 is sufficient for the preservation of milk.

As a qualitative test, the following simple procedure is satisfactory:—To about 3 c.c. of the milk placed in a test-tube add an equal volume of water, then introduce carefully at the bottom of the tube, by means of a pipette, 1 c.c. of strong sulphuric acid in such a way as to allow the dilute milk to float on the surface of the acid. Set aside for a time. If formaldehyde be

* Thresh and Porter: *Preservatives in Food and Food Examination*, London, 1906.

present, a violet ring will form at the junction of the two fluids. This test will detect 1 part of formaldehyde in 100,000 of milk. After being added to milk, formic aldehyde tends to disappear. Some experiments made by Tebb show that with 0·004 per cent. added, most of it is present after 53 hours, whilst with 0·001 per cent. all had disappeared by the following day.

The following quantitative test is given by Thresh,* and is based on the well-known reaction of aldehydes with bisulphites. The re-agents required are :—(*a*) a 20 per cent. solution of sodium sulphite, to which a very small quantity of phenol-phthalein has been added, and sufficient dilute sulphuric acid to just discharge the colour ; (*b*) a deci-normal solution of sulphuric acid. The process is conducted as follows : Take 20 c.c. of the sulphite solution, add thereto the solution suspected of containing formalin and obtained by distillation of the milk under examination, and allow to stand for three minutes. A pink colour appears, and the volumetric solution of acid is now run in carefully until this colour is discharged entirely. As each c.c. of the acid used corresponds to 3 mgm. of formic aldehyde, the quantity in the liquid is readily calculated.

Salicylic Acid.—This is not readily detected as so many organic substances interfere with the reactions. In the case of milk, if the sample contains an appreciable amount of this preservative, the addition of a solution of ferric chloride, sufficient to curdle the milk, will produce a pale brown colour, and in the separated whey a tint of violet may be detected. The difference is very marked when compared with a genuine milk. Salicylic acid is seldom employed alone for the preservation of milk, but is occasionally associated with mixtures containing boron compounds. We are unable to recommend a method for quantitative estimation.†

Hydrogen Peroxide.—This substance decomposes so quickly in milk that it can be detected but rarely. Even if added in excess to that required to "Buddeize" milk, its presence is capable of detection only for a few minutes after it has been added.

Sodium Carbonate.—Very difficult of detection unless in excess sufficient to render milk alkaline. Determine the ash and see if it effervesces, if so, either a carbonate has been added or sodium is united with lactic acid ; this will be converted into carbonate ; enough lactic acid to give an effervescing ash does not exist normally in good milk.

Salt has been known to be added to milk to the extent of 0·16 per cent., equal to 100 grains per gallon. It is a rare form of adulteration and should be detected by the excess of ash and a determination of the chlorine yielded by the ash after solution.

Tyrotoxicon.—This poisonous substance is present occasionally in milk and milk products. It is not a true toxin, but a diazo-benzene compound of very unstable character. Vaughan's process for its detection is as follows :—Filter the acidified milk and neutralise with sodium carbonate ; agitate with ether in equal volume, allow to stand in stoppered cylinder for twenty-four hours ; decant the ether and allow to evaporate spontaneously. Dissolve the residue in a small quantity of water ; on the addition of equal bulks of pure phenol and sulphuric acid an orange red to a green colour is given with very small traces of tyrotoxicon.

* Thresh and Porter, *op. cit.* p. 343 ; see also *Chemical News*, March 25, 1905.

† See *The Analyst*, 1900, p. 20 ; *also* 1903, p. 2.

LAW RELATING TO THE MILK TRADE.

In England and Wales.—Under section 117 of the Public Health Act, 1875, and under the 15th section of the Markets Clauses Act, 1847, unwholesome provisions, including milk, may be dealt with by seizure and condemnation. The Acts, however, which are most active in regulating the milk-supply are the Contagious Diseases (Animals) Acts, 1878-1886. Under these Acts (section 34 of 1878 and section 9 of 1886), the Local Government Board have power to make general or special Orders for (1) the registration with the Local Authority of all persons carrying on the trade of cowkeepers, dairymen, or purveyors of milk; (2) for the inspection of cattle in dairies and the general sanitation of dairies and cowsheds; (3) for securing the cleanliness of milk stores, shops, and vessels for containing milk; (4) for guarding milk against infection; (5) and for authorising Local Authorities to make regulations for any or all of the aforesaid purposes.

Under the powers thus conferred, the Local Government Board issued the Dairies, Cowsheds, and Milkshops Orders of 1885 and 1886, the chief effect of which Orders is to throw upon every urban and rural Sanitary Authority the duty of supervising the milk trade in their district, and of carrying out certain general regulations prescribed by the Orders. These duties are common to all districts alike, but any Sanitary Authority may arm itself with further powers by making regulations under section 13 of the Order of 1885, having the force of bye-laws. The chief provisions of the Order of 1885, as amended by that of 1886 and 1889, are summarised as follows:—

Section 6.—(1) It shall not be lawful for any person to carry on in the district of any Local Authority the trade of cowkeeper, dairyman, or purveyor of milk, unless he is registered as such in accordance with this article. (2) Every Sanitary Authority shall keep a register of such persons, and shall from time to time revise and correct the register. (3) The Sanitary Authority shall register every such person, but the fact of such registration shall not be deemed to authorise such person to occupy as a dairy or cowshed any particular building, or in any way preclude any proceedings being taken against him. (4) The Sanitary Authority shall from time to time give public notice of registration being required, and of the mode of registration. (5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making or selling butter or cheese, or both, and who is not also a purveyor of milk, need not be registered. (6) A person who sells milk of his own cows in small quantities to his workmen or neighbours for their accommodation need not, by reason thereof, be registered.

Section 7.—(1) It shall not be lawful to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order, until provision is made, to the reasonable satisfaction of the Sanitary Authority, for the lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply; (2) or without first giving one month's notice in writing to the Sanitary Authority.

Section 8.—It shall not be lawful for any . . . cowkeeper or dairyman to occupy as a dairy or cowshed any building—whether so occupied at the commencement of this Order or not—if . . . the lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply thereof are not such as are necessary or proper (*a*) for the health and good condition of the cattle therein; and (*b*) for the cleanliness of milk vessels used therein for containing milk for sale; and (*c*) for the protection of the milk therein against infection or contamination.

Section 9.—It shall not be lawful for any . . . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milkshop (*a*) to allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or to handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade . . . so far as regards the production, distribution, or storage of milk; or (*b*) if himself so suffering, or having recently been in contact as aforesaid, to milk cows or handle vessels containing milk for sale, or in any way to take part in the conduct of his trade as far as regards the production, distribution, or storage of milk; until, in each case, all danger therefrom of the communication of infection to the milk or of its contamination has ceased.

Section 10.—It shall not be lawful for any . . . cowkeeper, dairyman, or purveyor of milk, or . . . occupier of a milk store or milkshop after the receipt of notice of not less

than one month from the Local Authority calling attention to the provisions of this article to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or any room used as a milk store or milkshop.

Section 11.—It shall not be lawful for any . . . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milk store or milkshop, to use a milk store or milkshop in his occupation, or permit the same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk store or milkshop, and of the milk vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12.—It shall not be lawful for any . . . cowkeeper, or dairyman, or purveyor of milk to keep any swine in any . . . building used by him for keeping cows, or in any milk store or other place used by him for keeping milk for sale.

Section 13.—Any Sanitary Authority may from time to time make regulations for the following purposes, or any of them :—(*a*) For the inspection of cattle in dairies ; (*b*) for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water-supply of dairies and cowsheds . . . : (*c*) for securing the cleanliness of milk stores, milkshops and milk vessels used for containing milk for sale ; (*d*) for prescribing precautions to be taken by purveyors of milk, and persons selling milk by retail, against infection or contamination.

Section 14.—The following provisions shall apply to regulations made by any Sanitary Authority under this Order :—(1) Every regulation shall be published by advertisement in a newspaper circulating in the district of the Sanitary Authority. (2) The Sanitary Authority shall send to the Local Government Board a copy of every regulation made by them not less than one month before the date named for such regulation to come into force. (3) If at any time the Local Government Board are satisfied on inquiry with respect to any regulation that the same is of too restrictive a character, or otherwise objectionable, and direct the revocation thereof, the same shall not come into operation, or shall thereupon cease to operate, as the case may be.

Section 15.—The milk of a cow suffering from cattle plague, pleuro-pneumonia, or foot-and-mouth disease (*a*) shall not be mixed with other milk ; and (*b*) shall not be sold or used for human food ; and (*c*) shall not be sold or used for food of animals, unless it has been boiled.

Under the Dairies, Cowsheds, and Milkshops Order, 1899, the provisions of paragraphs (*a*) and (*b*), article 15, shall include in the case of a cow such disease of the udder as shall be certified by a veterinary surgeon to be tubercular.

The Amending Order of November 1886 imposed penalties of £5 for every offence against the Order of 1885, and, in the case of continuing offences, an additional daily penalty of 40*s*. The Courts have power to reduce the amounts of these penalties if they think fit.

The expenses of Sanitary Authorities under the Contagious Diseases (Animals) Acts, 1878 and 1886, are to be defrayed as if they were incurred in the execution of the Public Health Act, 1875, and in the case of rural authorities are to be deemed general expenses.

For the purpose of enforcing Orders under section 34 of the Act of 1878, and any regulations made thereunder, Sanitary Authorities and their officers will have the same right of entry as they have under section 102 of the Public Health Act, 1875, in respect of nuisances.

It is to be regretted that the Dairies, Cowsheds, and Milkshops Orders are not more adequately enforced by Sanitary Authorities ; the custom of combining the duties of inspection of dairies, &c., with that of inspectors under the Contagious Diseases (Animals) Acts, and employing police officers for these duties, gives very unsatisfactory results. Moreover, the power to make regulations is very inadequate, and Local Authorities have to be careful not to exceed their powers. Another defect is that there is no authority by which milk-sellers can be compelled to put notice boards or information as to their registration over their doors. To these criticisms may be added that the present state of the law is unsatisfactory in regard to disease among cattle. "Disease," as defined by the Contagious Diseases (Animals) Act, 1878, means "cattle plague, contagious pleuro-pneumonia, food-and-mouth disease, sheep-pox, or sheep-scab." No mention is made of tuberculosis ; an extension of the definition is very necessary.

Under section 3 of the Sale of Food and Drugs Act, 1879, the Medical Officer of Health, Inspector of Nuisances, or constable charged with the execution of the Act is empowered to procure, *at the place of delivery*, a sample of milk in course of delivery to the purchaser or consignee, in pursuance of any contract, and may submit the sample to the Public Analyst. "The seller, or his representative, if he refuses to allow a sufficient sample to be taken, is liable to a penalty not exceeding £10" (section 4). It is no defence to allege that the purchaser is not prejudiced by the sale of an adulterated article, on the ground that he bought it for analysis only; or to allege that the article in question, though defective in nature, or substance, or quality, was not defective in all three respects (section 2).

In London, by section 6 of the Local Government Act, 1899, it shall be the duty of each Borough Council to enforce within their borough the bye-laws and regulations for the time being in force with respect to dairies and milk, subject to the power of the London County Council to make bye-laws. Under the Public Health Act, 1891, section 28, powers are given to the Local Government Board to make Orders and regulations for dairies, and to the County Council and the Corporation of London to make bye-laws applicable to so much of the administrative county of London as is not included in the city, and in the city respectively.

In Scotland, under section 61, Public Health (Scotland) Act, 1897, power is given to the Local Authority, on representation by the medical officer or a medical practitioner that the outbreak or spread of infectious disease is attributable to milk, to require the dairyman to supply information and to produce a list of customers and invoices, and if the medical officer has evidence that any person is suffering from any infectious disease attributable to milk from any dairy, the Local Authority shall either make an Order requiring the dairyman not to supply any milk from the dairy, or they may resolve that no such Order is necessary. Any such Order shall be withdrawn on the Local Authority, or their medical officer on their behalf, being satisfied that the milk from the dairy is no longer likely to cause infectious disease.

In Ireland.—Section 34 of the Contagious Diseases (Animals) Act, 1878, applies to Ireland as well as elsewhere, and in pursuance of its provisions an Order in Council was made in August 1879, known as the Dairies, Cowsheds, and Milkshops Order of 1879, which is still in force as modified by the Act of 1886. This Order corresponds to, and is very similar to the English Order, above detailed, of 1885. Article 6 of the English Order corresponds to article 12 of the Irish Order; article 7 of the English is similar to article 5 of the Irish Order; while the articles 8, 9, 11, 12, and 15 of the English are the same as articles 6, 9, 10, 11, and 18 of the Irish Order. There are no articles in the Irish Order corresponding to 10 and 14 of the English Order, while in place of article 13 of the latter Order, similar provisions to it are placed in article 7 of the Irish Order.

There was no Irish Amending Order, imposing penalties, like that of the English one of 1886; but penalties are recoverable for offences against the Order of 1879, under sections 60 and 61 of the Public Health (Ireland) Act, 1878. In applying these enactments to Ireland, the Local Government Board for Ireland stands in precisely the same position as the English Board does to England. The expenses of Sanitary Authorities, under the Dairies Order, are defrayed as explained in the case of England and Wales; the same similarity exists as to powers of entry, section 118 of the Irish Public Health Act, 1878, being substituted for section 102 of the English Act of 1875.

We cannot leave this subject without calling attention to the urgent need of a reform of the country's milk-supply. Associated as it is with the problem of infant mortality, it constitutes a national question of the first importance. The problem of the milk-supply is really threefold, namely, (1) to prevent initial pollution at the time of milking; (2) to protect milk from subsequent fouling, either during transit to or storage in the home of the consumer; and (3) it must be produced at a price which will bring it within the reach of the poor. To prevent the first, attention must be directed to the farm. The cows must be healthy, and housed in byres or sheds so planned and constructed as to permit of these cattle remaining healthy. Further, the process of milking must be carried on with scrupulous cleanliness of cows, milkers and all utensils. The second line of prevention must ensure that milk, immediately after milking, be maintained at a temperature not exceeding 50° F., and that as soon as possible after cooling the milk be bottled, and the bottled milk be kept at even a lower temperature, say 40° F., until it is delivered to the consumer. By the precautions during milking, the initial contamination is minimised, and bottling would minimise home contamination. The third essential, or safeguarding of price, can only be obtained by the municipalisation of the milk-supply.

The present position of the law and details as to the legal provisions existing already for controlling milk-supplies have been discussed, but there is little doubt that further legislation is urgently necessary on the following lines. (1) To empower urban and rural sanitary authorities to inspect, in regard to tuberculosis and other disease, cows and cowsheds, wherever situated, from which milk is supplied to their districts. (2) To amend and extend the provisions of the Dairies, &c., Orders so as to make applicable to tuberculosis their regulations concerning the inspection of cattle. (3) That the power to make Regulations under the Order should be compulsory and not permissive; moreover, where this Dairies, Cowsheds and Milkshops Order is a dead letter, which undoubtedly is the case in many rural districts, the obligation to enforce the Order should devolve upon the County Council. Under section 13 of the Dairies, &c., Order, the Local Government Board have issued Model Regulations for prescribing and regulating the lighting, ventilation, cleansing, drainage and water-supply of cowsheds and dairies. The following are its provisions:—

1. The expression "cowshed" includes any dairy in which milking cows may be kept, and the expression "cowkeeper" means any person following the trade of a cowkeeper or dairyman required to be registered under the Order of 1885.

2. Every occupier of a dairy wherein any cattle may be kept, and which the Medical Officer of Health, or the Inspector of Nuisances, or any other officer of the Council specially authorised by them on that behalf, may visit for the purpose of inspecting cattle, and every person for the time being having the care or control of any such dairy, or of any cattle therein, shall afford such officer all reasonable assistance that may, for the purpose of the inspection, be required by him.

PART I.

The regulations in this Part shall apply to cowsheds the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day.

3. *Lighting.*—Every cowkeeper shall provide that every cowshed in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

4. *Ventilation.*—Every cowkeeper shall cause every cowshed in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the cowshed in a wholesome condition.

5. *Cleansing.*—(1) Every cowkeeper shall cause every part of the interior of every cowshed in his occupation to be thoroughly cleansed from time to time as often as may be so necessary to secure that such cowshed shall be at all times reasonably clean and sweet. (2) Such person shall cause the ceiling or interior of the roof and walls of every cowshed in his occupation to be properly limewashed *twice* at least in every year, that is to say, *once* during the month of May and *once* during the month of October, and at such other times

as may be necessary. Provided that this requirement shall not apply to any part of such ceiling, roof, or walls that may be properly painted, or varnished, or constructed of or covered with any material such as to render the limewashing unsuitable or inexpedient, and that may be otherwise properly cleansed. (3) He shall cause the floor of every such cowshed to be thoroughly swept, and all dung and other offensive matter to be removed from such cowshed as often as may be necessary, and not less than *once* in every day.

6. *Drainage.*—(1) Every cowkeeper shall cause the drainage of every cowshed in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to a drain inlet situate in the open air at proper distance from any door or window of such cowshed, or to some other suitable place of dispcsal which is so situate. (2) He shall not cause or suffer any inlet to any drain of such cowshed to be within such cowshed.

7. *Water-supply.*—(1) Every cowkeeper shall keep in, or in connection with, every cowshed in his occupation a supply of water suitable and sufficient for all such purposes as may from time to time be reasonably necessary. (2) He shall cause any receptacle which may be provided for such water to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein, and where such receptacle is used for the storage only of water he shall cause it to be properly covered and ventilated, and so placed as to be at all times readily accessible.

Part II.

The regulations in Part I., and also the following regulation, shall apply to all cowsheds other than those the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day.

8. A cowkeeper shall not cause or allow any cowshed in his occupation to be occupied by a larger number of cows than will leave not less than *eight hundred feet* of air-space for each cow. Provided as follows:—

(*a*) In calculating the air-space for the purposes of this regulation, no space shall be reckoned which is more than *sixteen feet* above the floor; but if the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof for the purposes of this regulation.

(*b*) This regulation shall not apply to any cowshed constructed and used before the date of these regulations coming into effect, until two years after that date.

Part III.

9. In this Part the expression "dairy" means a dairy in which cattle are not kept.

10. *Lighting.*—Every cowkeeper shall provide that every dairy in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

11. *Ventilation.*—Every cowkeeper shall cause every dairy in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the dairy in a wholesome condition.

12. *Cleansing.*—(1) Every cowkeeper shall cause every part of the interior of every dairy in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such dairy shall be at all times reasonably clean and sweet. (2) He shall cause the floor of every such dairy to be thoroughly cleansed with water at least *once* in every day.

13. *Drainage.*—(1) Every cowkeeper shall cause the drainage of every dairy in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable opening channel to the outside of such dairy, and may there be received in a suitable gully communicating with a proper and sufficient drain. (2) He shall not cause or suffer any inlet to any drain of such dairy to be within such dairy.

14. *Water-supply.*—(1) Every cowkeeper shall cause every dairy in his occupation to be provided with an adequate supply of good and wholesome water for the cleansing of such dairy and of any vessels that may be used therein for containing milk, and for all other reasonable and necessary purposes in connection with the use thereof. (2) He shall cause every cistern or other receptacle in which any such water may be stored to be properly covered and ventilated, and so placed as to be at all times readily accessible. (3) He shall cause every such cistern or receptacle to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein.

For securing the Cleanliness of Milk Stores, Milkshops, and of Milk Vessels.

15. *Cleanliness of Milk Stores and Milkshops.*—Every occupier of a milk store or milkshop shall cause every part of the interior of such milk store or milkshop to be thoroughly cleansed from time to time as often as may be necessary to maintain such milk store or milkshop in a thorough state of cleanliness.

16. *Cleanliness of Milk Vessels.*—(1) Every cowkeeper shall from time to time, as often as may be necessary, cause every milk vessel that may be used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water, and shall otherwise take all proper precautions for the maintenance of such milk vessel in a constant state of

cleanliness. (2) He shall, on every occasion when any such vessel shall have been used to contain milk, or shall have been returned to him after having been out of his possession, cause such vessel to be forthwith so cleansed.

FOR PRESCRIBING PRECAUTIONS AGAINST INFECTION OR CONTAMINATION OF MILK.

17. (1) Every purveyor of milk or person selling milk by retail shall take all reasonable and proper precautions, in and in connection with the storage and distribution of the milk, and otherwise, to prevent the exposure of the milk to any infection or contamination. (2) He shall not deposit or keep any milk intended for sale—(*a*) in any room or place where it would be liable to become infected or contaminated by impure air, or by any offensive, noxious, or deleterious gas or substance, or by any noxious or injurious emanation, exhalation, or effluvium; or (*b*) in any room used as a kitchen or as a living-room; or (*c*) in any room, or building, or part of a building, communicating directly by door, window, or otherwise with any room used as a sleeping-room, or in which there may be any person suffering from any infectious or contagious disease, or which may have been used by any person suffering from any such disease and not have been properly disinfected; or (*d*) in any room or building or part of a building in which there may be any direct inlet to any drain. (3) He shall not keep milk for sale, or cause or suffer any such milk to be placed, in any vessel, receptacle, or utensil which is not thoroughly clean. (4) He shall cause every vessel, receptacle, or utensil used by him for containing milk for sale to be cleansed thoroughly with steam or clean boiling water after it shall have been used, and to be maintained in a constant state of cleanliness. (5) He shall not cause or suffer any cow belonging to him or under his care or control to be milked for the purpose of obtaining milk for sale—(*a*) unless, at the time of milking, the udder and teats of such cow are thoroughly clean; and (*b*) unless the hands of the person milking such cow, also, are thoroughly clean and free from all infection and contamination.

PENALTIES.

18. Every person who shall offend against any of the foregoing regulations shall be liable for every such offence to a penalty not exceeding £5, and in the case of a continuing offence to a further penalty not exceeding 40*s*. for each day after written notice of the offence from the Council. Provided, nevertheless, that the justices or Court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this regulation.

A suggestive and temperate criticism of these Regulations has been made by a Committee appointed by the Royal Institute of Public Health to consider the best means to ensure a clean milk-supply to the consumer. Some recommendations of that Committee as to the construction and general management of farm buildings and as to transit of milk are worthy of study by the student and others interested in this subject.*

BUTTER.

As an article of diet, butter supplies to most people the largest amount of fat which they take. If the butter used in cooking be included, many persons take from 1½ to 2 ounces daily, but the average amount for persons in easy circumstances is 1 ounce daily. Butter appears to be easily digested by most persons, except when it is becoming rancid. It then causes dyspepsia and diarrhœa, but as a rule it may be said that decomposing fats of all kinds disagree.

Many observers have stated that butter made from tuberculous milk is also infective. Brusaferro found virulent tubercle bacilli in one sample out of nine and Gröning in eight out of seventeen samples. Rabinowitsch's experiments have thrown considerable doubt on these results. In twenty-three samples of butter, bacilli were found which produced lesions closely resembling those of tuberculosis. These pseudo-tubercle bacilli, however, could easily be distinguished from Koch's bacilli by both staining and cultural reactions. Eighty samples of butter were examined, but in no single case could true tubercle bacilli be found.

* *The Journal of Preventive Medicine*, vol. xiv. No. 12, December 1906, p. 706.

Composition.—Butter is really the fat of milk clotted together, and consists chiefly of neutral fats mixed with water and small amounts of casein and salts. Average butter may be said to have the following composition per cent. :—Fat, 78 to 94 ; curd, 1 to 3 ; water, 8 to 12 ; salt, 0 to 7. The flavour of a good butter is due to butyric and caproic acids, which constitute about 8 per cent. of the fat, the rest being composed of glycerides of oleic, stearic, and palmitic acids. When a butter has an objectionable taste, as in "turnipy" butter, this is due, not to pasturage, but to a special micro-organism which has found its way into the cream and set up a decomposition leading to the production of a taint. The casein averages 2·5 per cent., but may reach 7 per cent. if the butter is carelessly made. The water ranges from 8 to 12 per cent. in a good butter, but should never exceed 16 per cent. Milk-blended butters have been found to contain much more than this amount of water. The ash should not exceed 8 per cent., even in very salt butters ; in a pure fresh butter it is usually about 3 per cent.

Adulterations.—The chief and only important adulterations practised are the addition of water and the substitution of foreign fat. The addition of annatto or other harmless colouring-matter is not regarded as adulteration. Starch is added occasionally and may be detected by the blue re-action with iodine. The chief preservative added to butter is boric acid.

Examination of Butter.—This resolves itself mainly into the determination of the water and the proportion and composition of its fat. Occasionally it may be necessary to examine for boric acid.

The *water* is estimated by heating a weighed quantity of the sample over a water-bath until it ceases to lose weight. The regulations for the sale of butter, made in 1902, by the Board of Agriculture under section 4 of the Sale of Food and Drugs Act, 1899, provide that "where the proportion of water in a sample of butter exceeds 16 per cent., it shall be presumed for the purposes of the Sale of Food and Drugs Act, 1875 to 1899, until the contrary is proved, that the butter is not genuine by reason of the excessive amount of water therein."

For the detection of an admixture of foreign fat a variety of methods have been proposed, the principal being :—

(1) *The Valenta Test.*—This test depends on the miscibility of butter fat and strong acetic acid at a low temperature, whereas animal and vegetable fats do not form a clear mixture, except at much higher temperatures. The test is performed as follows ;—3 c.c. of melted butter fat and 3 c.c. of acetic acid (99 per cent.) are placed in a test-tube and a thermometer inserted ; heat is now applied, and if the butter fat is pure a clear solution will result when the temperature reaches about 91°·5 F. But no animal fat clears below 201° F., and no vegetable oil in common use clears below 176° F. This test enables a decision to be quickly given as to the purity of the sample.

(2) *Determination of the Specific Gravity of the Butter Fat.*—This can be estimated by melting the fat at 100° F., and then weighing in a specific gravity bottle. That of water being unity, a pure butter fat has usually a specific gravity of 0·911 to 0·913 ; an adulterated butter one of 0·902 to 0·904, and an artificial butter one as low as 0·859 to 0·861.

(3) *Determination of the Fixed Fatty Acids.*—This, though rather a difficult analysis to make, is most generally relied upon for giving an opinion as to the genuineness of butter. It is based on the fact that, when saponified with a caustic alkali such as soda or potash, and then decomposed with hydrochloric acid, the individual fatty acids which go to make up butter are obtained. A certain number of these are soluble in water while others are not, and it

is owing to the insoluble fatty acids obtainable from butter differing in amount from those obtainable from other animal fats that pure butter can be differentiated from artificial. The figures being, that if the insoluble fatty acids are over 89 per cent. there is an admixture of foreign fat. In a good butter the volatile fatty acids should not fall below 5 per cent. The process may be thus carried out :—Melt some of the butter in a test-tube or small beaker over a water-bath, and allow the water and solid particles to subside as much as possible ; then pour the melted fat upon a dry filter, care being taken to keep the aqueous solution in the tube or beaker, so as not to contaminate the fat. A double funnel, one with a warm-water jacket, is very convenient in order to keep the fat in a state of fusion. After filtering the fat through into a beaker, allow to cool and weigh. Next take out, with a glass rod, 3 or 4 grammes of the fat and put it into a large, deep and perfectly dry porcelain evaporating-dish. Now re-weigh the beaker and the fat left in it ; the loss in weight will represent the amount of butter fat about to be operated upon. The fat which was placed in the evaporating-dish is now melted on a water-bath, and about 50 to 70 c.c. of pure methylated spirit or absolute alcohol added. A clear yellow solution is formed. Now add from 1 to 2 grammes of caustic soda or potash, or 5 c.c. of a saturated solution of these alkalies in alcohol ; agitate by means of the glass rod, heating all the while, but taking care not to heat to boiling-point, as loss by spurting would be inevitable. Saponification proceeds rapidly, and is, in the case of butter fat, evinced by the strong smell of butyric ether, resembling the odour of pine-apples.

After two or three minutes, add a few drops of distilled water ; if turbidity, caused by undecomposed fat, ensues, continue the heating a little longer, the turbidity usually dissolving in the excess of alcohol. Keep on adding small quantities of water from time to time, until a considerable addition of it to the solution of soap no longer causes any precipitate of fat. Saponification is complete when any amount of dilution does not affect the transparency of the liquid. Should it happen that the water has been added too quickly, fat separates in the form of oily droplets, which now no longer dissolve in the too dilute alcohol. In this case, an additional quantity of alcohol may effect the solution, but it is preferable to begin the experiment afresh with a new quantity of butter fat.

The alcoholic solution of soap is continuously heated over the water-bath until all smell of alcohol has passed off ; if all the alcohol is not removed some of the fatty acids still remain in solution. When this has been done, the dish is nearly filled with water, in which the gelatinous soap, which has separated out on evaporating the liquid, readily dissolves. Dilute hydrochloric acid is now added, until strong acid reaction results, to liberate the fatty acids. These rise quickly to the surface as a white or creamy scum, with the evolution of a strong and disagreeable smell of butyric acid. The separated fatty acids are heated for half an hour on the water-bath, until they are perfectly fused into a clear oil, and the acid liquid below is also clear. Care should be taken that the water does not evaporate much.

Meanwhile, dry and weigh a filter-paper of about 5 inches in diameter. Moisten the filter and fill the jacket with boiling water ; then transfer every trace of oil from the dish and glass rod to the filter. Carefully wash out all the fatty acids from the dish to the filter by means of boiling water, and continue washing the filter well, until the filtrate gives no acid reaction with litmus paper. Usually about a litre of water is required. After all the water has run through the filter, the funnel in which it has been is emptied of its contained hot water, and the whole plunged into a beaker filled with

cold water, so that the levels of the fat inside and the water outside the funnel are the same. When the fatty acids are quite solidified, the filter is carefully taken out of the funnel, placed in a small weighed beaker and dried for two hours. It is now re-weighed, and the amount of insoluble fatty acids calculated as a percentage of the butter fat.

The percentage of insoluble fatty acids in butter fat, made from the milk of cows of the most varied breed, varies usually between 86·6 and 87·5, though in some rare instances it falls as low as 86·3, and rises as high as 88·5 per cent. A fair average is represented by the figure 87·3 per cent. All other animal fats furnish, on an average, 95·3 per cent. of insoluble fatty acids, or, in other words, there is a standard difference of 8 between the percentage of insoluble fatty acids in normal butter fat and that in other animal fats. From the percentage of the insoluble fatty acids found, it is, therefore, easy to draw conclusions as to the genuineness or otherwise of any given sample of butter. If the quantity of insoluble fatty acid be lower than 88 per cent., the butter must be declared genuine; if, however, the fatty acids are higher than 88·5 per cent., we may conclude that adulteration with foreign fat has taken place. The actual calculation will resolve itself into the following statement, as the constant difference, between the fixed fatty acids in normal butter and that in foreign fat, is to the observed difference, between the fatty acids found in the sample and those yielded by pure butter fat, so is the percentage of fat in the sample to the percentage of foreign fat in the sample.

(4) *Determination of the Volatile Fatty Acids.*—As an alternative to the foregoing determination, the following process, originally proposed by Reichert, and modified by Meissl and Wollny, affords a fairly reliable method of butter analysis. It is carried out as follows:—

Five grammes of the clear filtered butter fat are saponified on a water-bath in a flask, capable of holding 300 to 350 c.c. with 10 c.c. of a solution of pure caustic potash in 70 per cent. alcohol (20 grammes KHO in 100 c.c. alcohol). When the fat has completely dissolved, the alcohol is driven off slowly by gentle evaporation. The soap is then dissolved in 100 c.c. of water, decomposed with 40 c.c. of dilute sulphuric acid (1 in 10), and 110 c.c. distilled off, a few small pieces of pumice-stone having been added. 100 c.c. of this distillate are filtered and titrated with deci-normal alkali, rosalic acid or phenol-phthalein being used as an indicator. The number of c.c. used is increased by $\frac{1}{10}$th, corresponding to the total quantity of the distillate. The two chief sources of error in this method are a loss of butyric ether, and a gain by absorption of carbonic acid, hence it is advisable to carry out the saponification under a reflux condenser, and both distil off the alcohol and dissolve the soap in water in a closed flask.

Five grammes of genuine butter yield a distillate requiring from 28 to 31 c.c. of deci-normal alkali. Similar amounts of artificial butters, such as margarine, yield distillates requiring less than 1 c.c. of the alkali, and various butter mixtures demand intermediate quantities. The volatile fatty acids may be expressed in terms of butyric acid. One c.c. of the deci-normal alkali = 8·8 milligrammes of butyric acid; consequently, if the distillate from 5 grammes of butter fat requires 28 c.c. of deci-normal alkali, there will be 4·9 per cent. of volatile fatty acids present in the sample of butter fat.

Detection of Preservatives.—Salt is not often used alone as a preservative, as the quantity necessary (10 per cent.) would not be tolerated. The chief re-agent added to butter to preserve it is boric acid; the amount so added varies from 0·1 to 1·5 per cent. A Departmental Committee of the Board of Agriculture reporting on this matter suggested that in cream,

butter and margarine the use of borax or boric acid might be regarded as permissible provided the amount did not exceed 0·25 per cent. in cream, or 0·5 per cent. in butter or margarine. This recommendation so far has not received legal sanction.

For the estimation of boric acid in butter, the following method may be used. The percentage of water in the sample having been determined, weigh about 25 grammes of the butter into a 100 c.c. stoppered cylinder, and add sufficient distilled water to make, with the water already present, a number of cubic centimetres equal to the weight of butter in grammes. Add 15 c.c. of chloroform, warm to dissolve the butter, shake and set aside to separate. By means of a pipette remove an aliquot part of the watery liquid, render alkaline, evaporate to dryness and ignite. Treat the ash with hot water until all soluble matter is removed, make neutral to methyl-orange, boil to expel carbon dioxide, add 10 c.c. of glycerin, which renders it acid, and then titrate with deci-normal solution of soda, using phenol-phthalein as the indicator. As each c.c. of the soda solution equals 3·5 mgm. of B_2O_3 and each c.c. of the aqueous solution corresponds to one gramme of the original butter, the percentage of boric acid is easily calculated.*

MARGARINE.

This term is applied to fats, chiefly of animal origin, prepared by churning melted and clarified beef or mutton fat with skim milk, and so manipulating it as to resemble butter in appearance and flavour. For this purpose, a certain proportion of genuine butter is frequently mixed with it. Margarine consists mainly of olein, stearin and palmitin; it differs chemically from butter in containing only very small amounts of soluble fatty acids. When well prepared its nutritive value is probably little inferior to true butter. Margarine has been the subject of special legislation; this matter is conveniently summarised as follows:—

In order to prevent the fraudulent sale of margarine for butter, the Margarine Act, 1887 (now cited as the Sale of Food and Drugs Act, 1875 to 1899), was passed. Section 3 of this Act defines "butter" as made exclusively from milk, or cream, or both, with or without salt or other preservative, and with or without added colouring-matter. "Margarine" includes all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not. It is unlawful to manufacture, sell, expose for sale, or import any margarine, the fat of which contains more than 10 per cent. of butter fat. The expression "margarine cheese" means any substance, whether compound or otherwise, which is prepared in imitation of cheese, and which contains fat not derived from milk. No such substance may be lawfully sold, except under the name of margarine or margarine cheese and under the following conditions set forth in the Act:—

Every package of margarine or margarine cheese, whether open or closed, must be so marked as "margarine" or "margarine cheese" in printed capital letters not less than half an inch long, and the brand or mark shall be on the package itself and not solely on a label, ticket, or other thing attached thereto; and every person selling margarine by retail, save in a package duly branded or marked in accordance with the above requirements, must in every case deliver it to the purchaser in or with a paper wrapper on which is printed "margarine" in capital block letters not less than half an inch long

* Thresh and Porter, *op. cit.* p. 331.

and distinctly legible, and no other printed matter shall appear on the wrapper. All margarine factories must be registered with the Sanitary Authority by whom the Public Analyst of the district is appointed (section 9). Officers authorised to take samples under the Sale of Food and Drugs Act may take samples of butter, or substances purporting to be butter, exposed for sale and not marked as margarine, without going through the form of purchase required by that Act, but otherwise complying with its provisions as to dealing with the samples (section 10). Any such substances not being marked as margarine are to be presumed to be exposed for sale as butter, so that there is a possible offence under both Acts. There is a saving clause similar to section 25 of the Sale of Food and Drugs Act, namely, that the vendor is absolved if he proves that he bought the article with a written warranty, and sold it, in the same state as when bought, believing it to be butter (section 7). It is, however, no defence to allege that the purchaser is not prejudiced by the sale of an adulterated article, on the ground that he bought it for analysis only, or that the article is not defective in all three features of nature, substance and quality.

Penalties for offences under the Acts may not exceed £20 for the first offence, £50 for the second, and £100 for the third or any subsequent offence (section 4). Any part of these penalties may, if the Court so direct, be paid to the person who proceeds for the same, to reimburse him for the costs of obtaining the analysis, and any other reasonable expenses to which the Court may consider him to be entitled (section 1, Act 1899, and section 11, Act 1875).

CHEESE.

This is made from milk by the action of rennet, and consists of coagulated casein, with varying proportions of fat and salts. The different qualities of cheese depend mainly upon whether they are made from pure milk, from skimmed milk, or from a mixture of skim and whole milk. Thus, Cheddar, double Gloucester, Cheshire, and some American cheeses are made from whole milk, while Stilton is made from whole milk to which cream is added. Dutch, Parmesan, Suffolk, and Somersetshire cheeses are made from skimmed milk. Cream cheese consists of the fresh curd which has been moderately pressed ; it is eaten without being allowed to ripen. When a cheese is kept, it undergoes a change known as "ripening," which is supposed to be a decomposition, whereby the casein undergoes a fatty change, including the formation of lime salts of the fatty acids and the production of a soluble compound of phosphoric acid with casein, from the phosphate of lime usually present in milk.

As an article of diet, cheese is very valuable, being particularly rich in both protein and fat ; about $\frac{1}{2}$ lb. contains as much protein as 1 lb. of meat, and $\frac{1}{3}$ lb. as much fat. It does not, however, keep well in warm climates, and is occasionally very indigestible.

The percentage composition of some of the more common varieties is given in the Table on page 304.

The quality is known by the taste. The only adulteration is by substances added to give weight. Starch is chiefly employed, and can be detected by iodine. There is usually about 5 or 6 per cent. of salt.

Acarus domesticus, *Aspergillus glaucus* (blue and green mould), and *Sporendonema casei* (red mould), occur during decay. During decay, also, the fat augments at the expense of the casein ; leucin is produced, with valerianic and butyric acids. Lactic acid is also often produced, from

the lactose of the milk contained in the cheese. The aroma of cheese partly arises from this decomposition, and the production of volatile acids.

The maggots or larvæ of a fly (*Piophila casei*) are well known, and are frequently present in cheese undergoing decomposition.

Poisonous effects have followed the eating of cheese, which have been found to be caused by the presence of *Tyrotoxicon*, a substance which has been referred to under the subject of milk.

	Water.	Proteins.	Fat.	Free Acid as Lactic Acid.	Salts.
Cheddar	35·60	28·16	31·57	0·45	4·22
Cheshire	37·11	26·93	30·68	0·86	4·42
Single Gloucester	35·75	31·10	28·35	0·31	4·49
Dutch	41·30	28·25	22·78	0·57	7·10
American Red	28·63	29·64	38·24	—	3·49
Gorgonzola	32·50	32·80	31·20	—	3·50
Gruyère	32·00	35·10	28·00	—	4·80
Roquefort	26·50	32·90	32·30	—	4·40
Camembert	51·90	18·90	21·00	—	4·70

WHEAT.

As an article of diet, wheat is poor in water but rich in solids, therefore very nutritious in small bulk; the whole grain is somewhat indigestible, but when its outer coats are removed, is readily digested. The proteins in wheat are large and varied, consisting chiefly of a globulin and an albumose which, under the action of water, give rise to what is known as glutin. Whether all the globulin and albumose are transformed into glutin is uncertain, but the weight of evidence is in favour of the view that some escapes in a soluble form. The starchy substances are large, 60 to 70 per cent. are very digestible, and consist mainly of starch, sugar and dextrin. A nitrogenous ferment, called cerealin, is also contained in wheat, being closely associated with the internal coat of the grain. This body, like diastase, acts energetically in transforming starch into dextrin, sugar and even lactic acid. There is also present a small amount of fat, while the salts are chiefly phosphates of potash and magnesia. The chief defect in wheat, as an article of diet, is its poverty in fats and in vegetable salts which are required to form carbonates in the system.

As usually prepared, the grain is separated into flour and bran, the mean being 80 parts of flour, 16 of bran, and 4 of loss. The flour is itself divided into best or superfine, seconds or middlings, pollards or thirds or bran flour. In different districts different names are used. The wheats of commerce are named from consistence or colour (hard or soft, white or red); the hard wheat contains less water, less starch, and more glutin than the soft wheat.

To each wheat grain there are three envelopes surrounding a fine and very loose areolar tissue of cellulose filled with starch grains. The outer coat is made up of two or three layers of long cells, with slightly beaded walls, running in the direction of the axis of the grain. The hairs are attached to this coat, and are prolongations, in fact, of the cells. In the finest flour, the hairs and portions of this and the other coats may be found. The general structure of a wheat grain is shown in Fig. 28, from which it is seen to consist of a protective envelope or the bran, of an endosperm or kernel consisting

mainly of starch, and of a germ or embryonic layer, representing the young plant. This germ is characterised by its richness in protein and fat, while the bran shows a preponderance of cellulose and mineral matter. The chemical composition of the whole grain and its component parts is shown in the following table :—*

	Bran, 13.5 per cent.	Endosperm, 85 per cent.	Germ, 1.5 per cent.	Whole Grain, 100 per cent.
Protein	16·4	10·5	35·7	11·0
Fat	3·5	0·8	13·1	1·2
Starch and sugar	43·6	74·3	31·2	69·0
Cellulose	18·0	0·7	1·8	2·6
Mineral matter	6·0	0·7	5·7	1·7
Water	12·5	13·0	12·5	14·5

In the process of milling, the different parts of the grain are broken up. The outer coat yields bran, fine pollards, sharps and middlings, the germ is

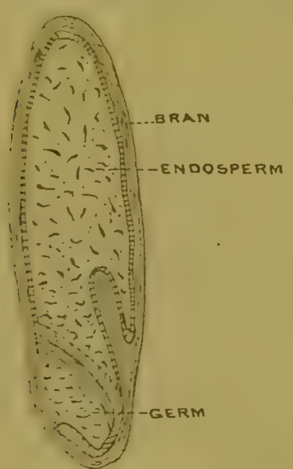


FIG. 28.—STRUCTURE OF A GRAIN OF WHEAT.

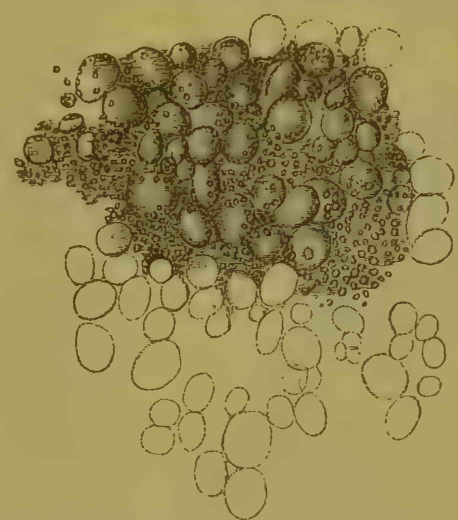


FIG. 29.—WHEAT STARCH GRAINS.

removed as offal, while the flour is derived solely from the endosperm. By careful milling the flour can be further subdivided into a small quantity of "patents," and a large quantity of "bakers" or "households." Coming from the centre of the endosperm, and owing to its purity, "patents" is reserved usually for the preparation of fancy breads and pastry. The common practice of rejecting the germ and bran entails the loss of the most useful constituents of wheat, for with the germ fat and protein are lost, and with bran mineral matter and the protein contained in its inner or aleurone layer of cells.

To avoid this waste, two patent processes have been devised. In the first or Smith's patent, the germ is killed by means of superheated steam, and its contained fat prevented from becoming rancid. The germ, so treated, is ground to a fine meal, and one part of this added to three parts of ordinary flour constitutes "Hovis" flour. Other processes of like nature are used to make the so-called germ breads, all being richer in protein and fat than ordinary bread. The second patent process deals with the bran and is the basis of "Frame Food." The bran is boiled with water under pressure, and from it is extracted most of the mineral salts and the nitrogen.

* Hutchison: *Food and Dietetics*, London, 1906.

After further filtration and evaporation this extract constitutes "Frame Food Extract," and is rich in nitrogen and mineral matter. The following table * shows the comparative composition of some of these different wheat preparations :—

	Wheat Meal.	Households or Medium Flour.	Patents or Finest Flour.	Hovis Flour.	Frame Food Extract.
Protein	14·2	10·7	7·9	15·5	16·5
Fat	1·9	1·1	1·4	3·2	1·0
Carbo-hydrates . .	70·6	75·4	76·4	70·0	63·9
Ash	1·2	0·5	0·5	2·3	8·8
Water . . .	12·1	12·3	13·8	12·2	9·8

The starch grains of wheat (Fig. 29) are very variable in size, the smallest being almost mere points, the largest $\frac{1}{1000}$th of an inch in diameter or larger. In shape the smallest are round, the largest round, oval, or lenticular. There is often a singular want of intermediate-sized grains. The hilum, when it can be seen, is central, the concentric lines are perceived with difficulty, and only in a small number ; the edge of the grain is sometimes turned over so as to cause the appearance of a slight furrow or line along the grain.

FIG. 30.
1. TILLETIA CARIES.
2. TILLETIA LÆVIS.
3. USTILAGO CARBO.

The wheat grains should be carefully examined for any diseased forms. Frequently small, short, thick and blackish grains are found. If these characteristically modified grains be steeped in water for some hours, the microscope will reveal inside them briskly mobile worms from 0·6 to 1 mm. in length. These are known as the *Anguillulæ tritici*, and the condition they give rise to is called cockle disease of wheat.

A number of fungi of the family of the Ustilagineæ frequently destroy corn grains. The chief of these are *Ustilago carbo*, *Tilletia caries*, and *Tilletia lævis*. *Ustilago carbo* or smut forms a black dusty powder, occupying the glume in place of the grain, which is entirely destroyed. The spores are almost regularly globular, light brown and smooth (Fig. 30 [3]). *Tilletia caries* and *T. lævis*, sometimes called the canker or stinking disease of wheat, are fungi which, microscopically, are very similar to each other, and fill the grains with a moist, smeary, black powder. Microscopically, the spores of Tilletia are larger than those of Ustilago. In *T. caries* (Fig. 30 [1]), they are globular or roundish with net-like ridges ; in *T. lævis*, they are more irregular and smooth (Fig. 30 [2]).

If flour be adulterated with rye, it may contain the mycelium of a fungus called the *Claviceps purpurea* or ergot of rye. At present, however, it is rare to find ergot in flour, as it is carefully sought out on account of its value as a drug.

Of the several fungi found in wheat flour, the most common are the Ustilagineæ already mentioned and an Uredinaceous species called the *Puccinia graminis* (Fig. 31). It is easily recognised by its round dark sporangia, which are either contoured with a double line, or are covered with little projections. The accompanying drawing shows a section through part of a grain of wheat attacked by puccinia ; the sprouting teleutospores

* Hutchison : *Food and Dietetics*, London, 1906.

are clearly seen growing on the surface of the grain. The symptoms which this fungus may give rise to have not been well described, there being some doubt as to whether it really is injurious to man at all.

The *Acarus farinæ* (Fig. 32) is by no means uncommon in inferior flour, especially if it is damp. It does not necessarily indicate that leguminous seeds are present, as stated. It is no doubt introduced from the grain in the mill, as it has been found adhering to the grain itself. It is at once recognised. Portions of the skin are also sometimes found.

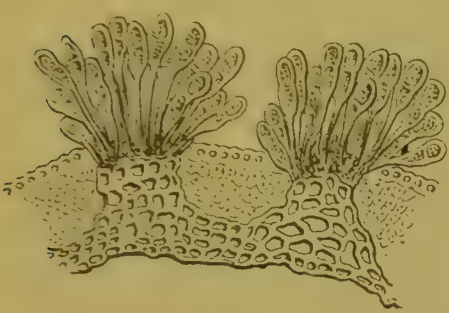


Fig. 31.—Wheat Grain affected with Puccinia.

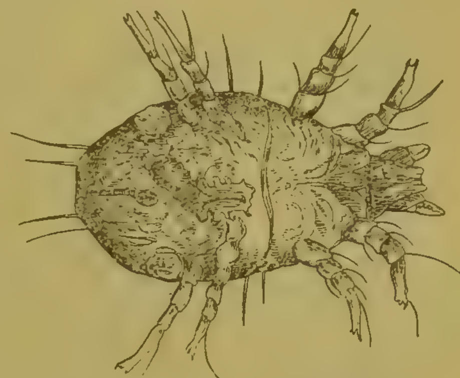


Fig. 32.—Acarus Farinæ.

The presence of *acari* always show that the flour is beginning to change. A single acarus may occasionally be found in good flour, but even one should be looked on with suspicion, and the flour should be afterwards frequently examined to see if they are increasing in numbers. In flour which has gone to extreme decomposition, and is moist and becoming discoloured, vibrios and other forms of bacterial life are frequently seen. They cannot be mistaken.

Another organism occasionally met with in flour is the *Calandra granaria* or weevil (Fig. 33), while somewhat rarer are the larvæ of various kinds of

Fig. 33.—Calandra Granaria.

moth, more particularly *Ephestia elutella* and *Ephestia kuehniella* belonging to the micro-lepidoptera.

Adulterations of Flour.—At present there is very little adulteration of wheat flour in this country, but with rising prices the case might be different. Possible adulterations are by the flour of other grains, such as peas, beans, maize, oat, rye, rice, &c., but, in addition, mineral substances, such as clay, flint, gypsum, are found in flour. The majority of these are easily detected by the microscope. Among the rarer adulterations are *Melampyrum* and *Lolium temulentum*.

Melampyrum arvense, or purple cow-wheat, has been occasionally mixed with flour; it is not injurious, but gives the bread made from the flour which contains it a peculiar smoky-violet or bluish-violet tint. This appears

to be due to a colouring-matter in the seed, which, when warmed with an acid, gives the violet tint.

Lolium temulentum, or Darnel seeds, occasionally have been found in flour. They do not affect the colour of the bread, but produce vertigo, hallucinations, delirium, and narcotic symptoms. The detection of *lolium* is best effected by means of alcohol, which gives a greenish solution with a disagreeable repulsive taste, and on evaporation a resinous, yellow-green and unpleasant extract is left. Pure flour gives with alcohol only a clear straw-coloured solution, with a more or less agreeable taste.

Of the preparations of flour, bread is the most important; while of less importance are biscuits, macaroni, and vermicelli.

Examination of Flour.—Every sample of flour should be examined microscopically, physically, and practically by making bread. While adulterations are best determined by the microscope on the lines already indicated, the quality is best demonstrated by attention to the following points :—

It should be white in colour, silky to the touch and free from any smell or odour suggestive of acidity or mouldiness. Yellowness, acidity and grittiness are invariable signs suggestive of either an old or a degraded flour. Of direct estimations, the two most important are the amount of its glutin and the bread-making qualities of a flour.

Amount of Glutin.—Weigh 10 grammes and mix by means of a glass rod with a little water, so as to make a well-mixed dough, adding the water slowly from a burette : usually for 10 grammes of flour not more than 4·2 c.c. of water are needed. When made, let the dough stand for a quarter of an hour in an evaporating-dish ; then pour a little water on it ; work it about with the rod, and carefully wash off the starch ; pour off, from time to time, the starch water into another vessel. After a time, the glutin becomes so coherent that it may be taken in the fingers and worked about in water, the water being from time to time poured off till it comes off quite clear. If there is not time to dry the glutin, then weigh ; the dry glutin is rather more than one-third the weight of the moist ; 1 to 2·9 is the usual proportion ; therefore divide the weight of the moist glutin by 2·9. If there be time, dry the glutin thoroughly, and weigh it. This is best done by spreading it out on a crucible lid and drying it in the hot-air bath. The dry glutin ranges from 8 to 12 per cent. ; flour should be rejected in which it falls below 8. If there is much bran, it often apparently increases the amount of glutin by adhering to it, and should be separated if possible ; in fact, the glutin, as thus obtained, is never pure, but always contains some bran, starch, and fat. The glutin should be able to be drawn out into long threads ; the more extensible it is the better. It is always well to make two determinations of glutin, especially if there is any disputed question of quality.

Practical Test by Baking.—Make a loaf, and see if it is acid when fresh, and how soon it becomes so ; if the colour is good ; and the rising satisfactory. Old and changing flour does not rise well, gives a yellowish colour to the bread, and speedily becomes acid. Excess of acidity can be detected by holding a piece of bread in the mouth for some time, as well as by test-paper.

BREAD.

If carbon dioxide gas is, in any way, formed within or forced into the interior of dough, so as to divide the dough into a number of little cavities, bread is made. There are practically two kinds of bread, namely, that made

by means of yeast, and that aerated by chemical means or the non-fermented bread. The ordinary process of bread-making consists really of three stages, namely, the preparation of the leaven or ferment, the preparation of the "sponge," and the making of the dough.

One sack of flour, weighing 280 lb., is usually reckoned to yield from 376 to 384 lb. of bread, or from 94 to 96 quartern loaves, and in making bread from this amount of flour the following procedure is usually adopted :—

First, the ferment or leaven is made with 8 to 12 lb. of boiled potatoes mashed into a thin paste. After cooling to about 80° F., or 27° C., a quart of brewer's yeast and 2 lb. of flour are added. In this mixture of potato starch, flour, and yeast, the yeast decomposes the proteins of the flour and the starch, forming maltose, dextrin, and peptone-like bodies. At the same time the yeast becomes very active. The process is allowed to go on for five hours.

To the ferment when ready, one-third of the sack of flour, 48 ounces of salt, and 30 quarts of water are added. If the flour is very good, the salt is not necessary; and even with the inferior flours, if in excess, will check the fermentation. The resulting mixture constitutes the "sponge" in which very active fermentation goes on ; after about five hours, the sponge breaks, owing to the development of large quantities of carbonic acid and alcohol from the maltose and dextrin. When the sponge has broken twice, the dough is formed by adding to the sponge the remainder of the sack of flour and some 30 quarts of water. This rises in an hour or so, and is then transferred to an oven for an hour and a half. Though the temperature of the oven varies from 400° to 450° F., or from 204° to 232° C., the actual temperature of the dough does not rise much over 212° F., or 100° C. In this stage the chemical processes are not very active, but the bread gradually becomes well aerated, and its constituents, undergoing a kind of automatic digestion, improve both in flavour and aroma.

In the non-fermented breads, the carbon dioxide is disengaged by mixing sodium or ammonium carbonate with the dough, and adding hydrochloric, tartaric, phosphoric, or citric acids. Baking powders are compounds of these substances. In what is called Dauglish's patent aerated bread, the carbonic acid is forced through the dough by pressure. About 20 cubic feet of carbon dioxide, derived from chalk and sulphuric acid, are used for 280 lb. of flour, and about 11 cubic feet are actually incorporated with the flour. It is claimed for unfermented breads that they do not contain alcohol, acetic acid, and other products of excessive fermentation, but the advantage is a doubtful one, as the action of yeast partially digests the starch, changing it into maltose and dextrin ; while the proteins of flour are also largely converted into albumoses or other peptone-like bodies.

Chemical Composition of Bread.—From what has been said about the making of bread, it is obvious that bread differs in composition from flour. The percentage composition of some ordinary breads is given in the Table on page 310.

As an article of diet, bread has very similar advantages and disadvantages as flour. It is rich in protein and starch, but poor in fat and salts. Roughly speaking, its nitrogen is to the carbon as 1 is to 21. To make it a perfect food, it requires therefore more nitrogen. The poverty in fat is curiously exemplified by the constant practice of using fat with it : butter for the rich, and dripping or fat bacon for the poor. As to the relative advantages of the various methods of making bread, it must not be overlooked that yeast bread is nothing more nor less than a partially digested flour, and as such holds a superior dietetic position to the non-fermented forms of bread.

	Water.	Proteins.	Fats.	Starch.	Sugar.	Cellulose.	Salt.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
White bread, average quality .	40·10	8·00	1·50	49·20	—	—	1·30	1 is to 6·3
White bread, fine quality . .	35·59	7·06	0·46	52·56	4·02	0·32	1·09	1 " 7·5
White bread, coarse quality . .	40·45	6·15	0·44	49·04	2·08	0·62	1·22	1 " 8·1
Whole-meal bread.	43·40	11·10	0·40	41·90	—	1·70	1·50	1 " 4·0

Examination of Bread.—A good bread should be white in colour; any yellowness is suggestive of either an old flour, bad yeast, or a mixture of rye or bran in the flour. In every loaf there should be a due proportion of crust whose external surface should not be burnt. The amount of crust can be readily estimated by carefully paring it off with a sharp knife, weighing, and then calculating it as a percentage of the weight of the whole loaf. The crumb should be permeated with small regular cavities; no parts should be heavy, nor without these little cells; the partitions between the cavities should not be tough; the colour should be white or brownish from admixture of bran; the taste not acid, even when held in the mouth. If the bread is acid the flour is old, or bad leaven has been used; if the colour changes soon, and *fungi* form, the bread is too moist; if sodden and heavy, the flour is bad, or the baking is in fault; the heat may have been too great, or the sponge badly set.

The purely chemical examination of bread should be directed chiefly to the determination of the water and acidity.

Amount of Water.—This should be calculated on the whole loaf, and determined separately in both the crust and crumb. Usually it amounts to about 16 per cent. in the crust, and from 35 to 45 per cent. in the crumb. On the whole loaf it should not be more than 45 per cent.; if more, the bread is *pro tanto* less nutritious, and liable to become mouldy sooner. The determination is readily made by taking a weighed quantity of the powdered bread, drying in a hot-air bath or oven, re-weighing, and calculating out as a percentage.

Degree of Acidity.—This is a somewhat important determination, and can be readily made by means of a standard alkaline solution, prepared by taking liquor sodæ or liquor potassæ of pharmacopœial strength, and diluting with 8 to 9 parts of distilled water, so that 10 c.c. exactly neutralise 10 c.c. of a deci-normal solution of oxalic acid. If so prepared, 1 c.c. of the alkaline solution equals 6 milligrammes of glacial acetic acid, in terms of which the acidity of bread is usually expressed. The acidity of bread is conveniently determined by soaking, for an hour, 10 grammes in 100 c.c. of distilled water, macerating, and then titrating with the standard alkaline solution; either litmus and turmeric papers or phenol-phthalein may be used as indicators. As in the case of the moisture, the acidity should be separately estimated for the crust and crumb, and then calculated on the whole loaf. The actual acidity found will vary; even the best bread is slightly acid. It generally averages from 4·5 to 6 grains per pound, or from 0·064 to 0·086 per cent. Eight grains per pound, or 0·114 per cent., of glacial acetic acid ought certainly to be the limit.

Diseases due to Faulty Flour and Bread.—Although disease is traceable rarely to the use of cereals, still it is unwise to ignore the possibility. Mouldy flour and mouldy bread are both known to have

caused illness. The symptoms produced by bread containing *Lolium temulentum* have already been described; while as to the effect of flour from grains other than wheat, it is not known whether the addition of potatoes, rice, barley, peas, &c., in any way injures health, except as it may affect nutrition or digestion. Occasionally, in times of famine, other substances are mixed—chestnuts, acorns, &c. In 1835, during famine, fatal dysentery appeared in Königsberg owing to the people mixing their flour with the pollen of the male catkin of the hazel-bush. In India the use of a vetch, *Lathyrus sativus* (kisārī-dāl), with barley or wheat, gives rise to a special paralysis of the legs when it exceeds one-twelfth part of the flour; *L. cicera* has the same effect. During the siege of Paris, straw, to the extent of one-eighth, was introduced into the bread; this had a very irritating effect.

LAW RELATING TO BAKEHOUSES.

Under the Factory and Workshop Act, 1901, Bakehouses call for their share of attention from District Councils in the ordinary way; that is to say, if no mechanical power is employed they rank as workshops and must comply with all the sanitary requirements laid down by the Act for Workshops; if mechanical power is employed they are factories, and in connection with such the District Council *may* be concerned with the question of safety from fire or the provision of adequate closet accommodation. A "retail" bakehouse means "any bakehouse or place (not being a factory) the bread, biscuits or confectionery baked in which are not sold wholesale but by retail, in some shop or place occupied together with such bakehouse." The same Act places the sanitary supervision of these "retail" bakehouses in the hands of the Sanitary Authorities; these Authorities, outside the metropolis, are the District Councils; in London they are, in the City, the Corporation, and elsewhere the Borough Councils.

The powers and duties of a Medical Officer of Health in connection with the sanitary regulation of retail bakehouses are somewhat exceptional. He has all the powers of entry, inspection, taking legal proceedings and otherwise, of a Factory Inspector. He is also required, if he becomes aware of the employment of any child or young person under eighteen years of age, or woman in any retail bakehouse, to forthwith give written notice thereof to the Factory Inspector of the district. The powers of entry and inspection conferred on the Medical Officer of Health are such that he may enter, inspect, and examine any retail bakehouse at any reasonable time by day or by night, without any special written authority or warrant.

No bakehouse may contain or communicate directly with a water-closet or privy, nor derive its water from a cistern supplying a closet. A drain or pipe for carrying off fæcal or sewage matter must not have an opening in the bakehouse. The penalty for contravention of these rules is £2, and a daily penalty of 5*s*. for continuance after conviction (section 97). A Court of Summary Jurisdiction, satisfied on the evidence of a Factory Inspector or a Sanitary Authority that a bakehouse is unfit on sanitary grounds, may impose a penalty and require the necessary alterations to be made (section 98). The walls and ceilings of rooms, passages and staircases must be limewashed every six months; or receive three coats of oil paint or varnish every seven years, and be washed with hot water and soap every six months (section 99). A part of the same building, on the same level with the bakehouse, must not be used as a sleeping-room unless partitioned off from floor to ceiling, and having an external glazed window 9 square feet in area, of which 4½

feet are made to open for ventilation (section 100). *Underground bakehouses* are those in which any room used for baking or processes incidental thereto has its floor more than 3 feet below the footway of the adjoining street or ground adjoining or nearest to the room. Such an underground bakehouse must not be used as such unless (*a*) it was so used on August 17, 1901, and further (*b*) the Sanitary Authority has certified it to be suitable as regards construction, light, ventilation and in all other respects (section 101).

In all places where food is prepared a high standard of sanitation is needed. The following points are specially applicable to bakehouses :—Rooms to be not less than 8 feet in height ; minimum air-space to be 400 cubic feet per head and 1500 cubic feet in all clear of ovens, machinery and stored goods. In the case of underground bakehouses there must be 500 cubic feet of space to every person. Floors to be laid with proper falls and drained by proper channels to an outside gully. Surfaces of floors, walls and ceilings to be hard, smooth, durable and impervious. Tables, benches and troughs to be freely movable. All shelves to be fixed 2 inches away from walls. Oven furnaces to have flues to carry away fumes. Lighting to be natural if possible, otherwise electric or incandescent burners. Ventilation to be by fan if necessary. Temperature not exceeding 60° F. ordinarily or 80° F. within half an hour after drawing an oven.

BISCUITS.

The simplest biscuits are merely flour and water, but the majority have slight additions of butter, sugar, and flavouring substances, with milk, eggs, &c. What are known as diet or digestive biscuits contain some bran. Abernethy biscuits contain caraway seeds. Cracknels are glazed with white of egg, while macaroons and ratafias are flavoured with sweet and bitter almonds. Ginger, lemon, orange-peel, and many other flavours and spices are used as ingredients in fancy biscuits and cakes.

Biscuits should be well baked, but not burnt ; of a light yellow colour, should float and partially dissolve in water. When struck, they should give a ringing sound, and when put into the mouth should thoroughly soften down. All biscuits should be free from weevils. All the plainer varieties of biscuit may be considered as more nutritious than bread, in the proportion of 5 to 3. They are more digestible when not very dense, and when they have been browned by baking, so as to turn much of their starch into dextrin. Like flour, biscuit is deficient in fat, and after a time seems difficult of digestion. Perhaps the want of variety is objectionable, but it is quite certain that men do not thrive well upon it for long periods.

The essential differences between biscuits and bread are that they are not vesiculated, and they are baked until they contain scarcely any water, sometimes not even 5 per cent. There are, of course, some exceptions to this rule, especially in the case of the fancy biscuits. Strictly speaking, a biscuit is that which has been twice cooked or baked, but this definition will not apply to the generality of biscuits now made. A few kinds are really put twice into the oven ; such are rusks, which are made from flour, milk, butter, and sugar, first lightly baked as a kind of bread, then cut into slices and again put into a sharp oven so as to scorch both sides. They are afterwards thoroughly dried by a lower degree of heat continued for some hours.

The percentage composition of two varieties of plain biscuit may be taken to be as follows :—

	Water.	Proteins.	Fats.	Starch.	Sugar.	Cellulose.	Salt.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Navy biscuit . .	10·20	10·90	1·60	75·00	—	1·20	1·10	1 is to 7
Milk biscuit . .	9·45	7·18	9·28	57·18	15·92	0·16	0·83	1 „ 14

From the foregoing, it will be readily seen that biscuits contain a much smaller quantity of water and a larger proportion of protein and carbo-hydrate than bread. Weight for weight, they are therefore more nutritious than bread, and being easily transported are useful as a substitute for bread, when this cannot be obtained.

Besides biscuits and bread, other preparations from flour are macaroni and vermicelli. *Macaroni* is made from the "hard" wheats of Italy and France. These wheats yield large quantities of glutin, and readily permit of the manufacture of the macaroni of commerce. Macaroni is a valuable food, little appreciated in these islands, and of a fairly constant composition. It contains, on an average, 13 per cent. of water, 9 of proteins, 0·4 of fat, 76·7 of carbo-hydrates, and 0·9 per cent. of salts. *Vermicelli* closely resembles macaroni in both its composition and nutritive properties.

BARLEY.

As an article of diet, barley has the same advantages and disadvantages as wheat. It is said to be rather laxative. The barley grain contains about as much protein as wheat, but this does not, on the action of water, form glutin, but remains in a soluble form as globulin, albumin and albumose. It is difficult to say how far this affects its nutritive value, but it undoubtedly affects the capability of barley being made into bread, and as such being largely used as an article of diet.

The envelopes of barley are the same in number as those of wheat, but they are more delicate. The outer coat is described usually as having three layers of cells; the walls of the external layer are beautifully waved, but not beaded; the individual cells are smaller than those of the outer coat of wheat. The second coat, having cells disposed at right angles to those of the first, is like the second coat of wheat, except in being more delicate and not beaded. The third is hyaline and transparent, with faint cross-lines, as in wheat, but the cells are very much smaller.

The starch grains of barley are very like the wheat, with a central hilum and obscure marking, but are on the whole smaller; some have thickened edges, instead of the thin edges of the wheat starch grains, but it is very difficult and sometimes impossible to distinguish them. It is therefore specially to the envelopes that we must attend.

When the whole barley grain is ground, it forms *barley-meal*; when deprived of its husk, and roughly ground, it constitutes *Scotch*, *milled*, or *pot barley*. *Pearl barley* is the grain deprived of the husk, rounded and polished by rubbing. So-called *patent barley* is merely pearl barley crushed to the state of flour. Barley-water is prepared from pearl barley, and forms a slightly nutritive liquid for infants and the sick. *Malt* is the product yielded when barley has been allowed to germinate, and the germination stopped at a certain point by exposure to heat on a kiln. As a result of this process, the starch of the grain is largely converted into sugar by the development within the barley grain of a peculiar active nitrogenous ferment

called diastase. As there is little or no glutin in barley, it cannot be made into ordinary bread; when barley bread is made, it is usually from a mixture of barley-meal with wheaten flour. Barley cakes are eaten in some places on the score of economy; but, as compared with those made from wheat, are less palatable and less digestible.

The diseases which may arise from altered quality of barley are the same as those from wheat, namely, indigestion, flatulence, and diarrhœa. There appears to be nothing peculiar in the action of diseased barley as distinguished from diseased wheat.

RYE.

Although little used in this country except for malting, rye in the northern countries of Europe is largely used for making bread. The percentage composition of rye closely resembles that of wheat, its proteins forming, on the addition of water, a kind of glutin. Rye bread is dark in colour, somewhat heavy and very acid; but falls little short of wheaten bread in nutritive value.

Rye bread is indigestible and apt to cause diarrhœa. If mixed with two parts of wheat flour, rye flour makes an excellent bread.

Percentage Composition of Rye Bread.

	Water.	Protein.	Fat.	Starch.	Sugar.	Cellulose.	Salts.
German rye bread . .	42·26	6·11	0·43	46·94	2·31	0·49	1·46
„ black bread . .	43·42	7·59	1·51	41·87	3·25	0·94	1·42

The envelopes of rye are very like those of wheat, and can perhaps hardly be distinguished from them. The recent starch grains (Fig. 34) are also like those of wheat, but they are much more distinctly spherical. They have also sometimes a peculiar rayed hilum, which used to be thought peculiar to the older and drier grains. It is, however, to be seen even in the starch of fresh soft grains. In the starch of wheat, this rayed hilum is only met with occasionally, when the grain is very old or dry. If rye flour is mixed with ordinary wheat flour it is readily discoverable by baking, as it makes a dark, acid bread.

Fig. 34.
Rye Starch Grains.

Rye is subject to a very peculiar fungus disease due to the permanent mycelium of the *Secale cornutum*, which grows at the expense and in place of a grain of the corn, producing what is called an ergot of rye. If we take a spike of ergotised rye, we see one or more of the rye grains replaced by blackish horn-like growths, twice or three times as long and stout as the normal rye grains (Fig. 35). This is the ergot, and when fresh has a faint sickly odour, with a bitter and nauseous taste; from it ergotine is produced. This black grain or ergot is not a perfect fungus, but is really a sclerotium or permanent mycelium of the *Secale cornutum*. If this sclerotium or ergot be placed in a clean, moist, shady place it will germinate (Fig. 36) producing on its surface several club-shaped growths. Each little white-stemmed

off-shoot from the ergot has a small spherical head of a beautiful purplish colour. This growth is now the perfect condition of the ergot, and is termed *Claviceps purpurea*. The claviceps derives its nourishment from the ergot, and after it has appeared the ergot collapses and perishes. If one of the heads or clubbed ends of the claviceps be cut through longitudinally, it will be found to have the structure as shown in Fig. 37. Its outer surface is seen to be packed all round with small flasks, conceptacles or *perithecia*, with their mouths all opening to the outside. Each single perithecium is closely packed with fine long transparent bladders, each of which again contains some eight or ten fine, long attenuated bodies, which are sporidia or spores. When ripe, these needle-like spores are ejected into the air, whence they ultimately find

FIG. 36.—GERMINATING ERGOT.

attachment to the base of the pistil of a flower of rye. Here it germinates, to form, in course of time, a sclerotium or ergot, with a subsequent development of the claviceps stage.

When the ergot gets mixed with rye grains, and is ground with them, the resulting bread

FIG. 35.—SPIKE OF ERGOTISED RYE.

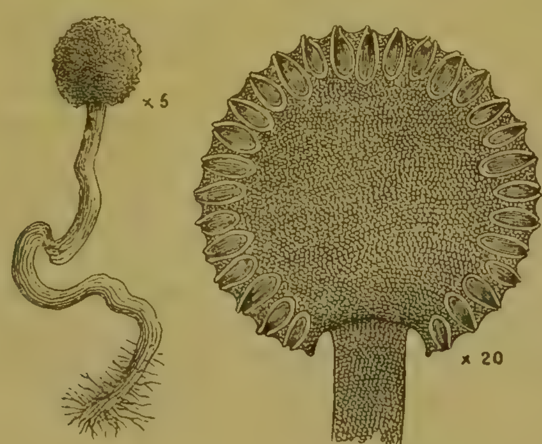


FIG. 37.—CLAVICEPS PURPUREA.

gives rise to a disease in men called ergotism, the symptoms of which are vomiting, diarrhœa, followed in severe cases by either loss of sensibility, gangrene, or paralysis. The disease is practically unknown in this country, and much less prevalent now than formerly abroad. On account of their size, the ergots can be readily sifted from the unaffected grains; as already stated, the ergot is carefully sought out, owing to its value as a drug, and for this reason is rarely found in flour.

OATS.

As met with in commerce, oats consist of the seeds of the *Avena sativa* enclosed in their husks. When deprived of this integument, the grain goes by the name of *groats* or *grits*, used in making porridge; and these groats, when ground down fine, constitute *oat-meal*, from which gruel is made. Of all the cereals, oats rank next to wheat as articles of food, being noticeable for containing large amounts of protein and fat—particularly the latter. Oats resemble barley rather than wheat, in that their proteins do not form glutin on the addition of water; on this account oat-meal cannot be made into bread like wheaten flour. It is, however, made into thin cakes by mixing into a paste with water, and then baking on an iron plate. Owing to the large amount of cellulose which they contain, these cakes are apt to irritate the intestines, and more or less interfere with digestion.

In oats, there are two or three envelopes: the outer coat contains longitudinal cells; the second contains obliquely transverse cells, which are not very clearly seen; the cells are wanting in parts, or pass into the cells of the third coat, which is a layer, usually single, of cells like the third coat of wheat. The husk must be detached before the envelopes are looked for, since lining it is a layer of wavy cells, like the external envelope of barley, which might mislead. The starch cells are small, many-sided, and cohere into composite round bodies, which (Fig. 38) are very characteristic, and can be broken down into the separate grains by pressure. A high power is necessary for the examination of these grains. The oat starch does not polarise light, and there is usually no difficulty in detecting the grains by means of the microscope.

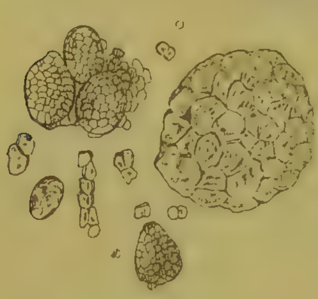


Fig. 38.—Clumps of Oat Starch Grains.

Oats can be taken for long periods without distaste in the form of oat-meal, which constitutes a material part of the dietary of the Scotch peasantry. The chief adulterations of oat-meal are barley meal and the husks of barley, of wheat and of the oat itself. A single look through the microscope usually detects the round and smooth barley starch, while the envelopes are recognised with very little more trouble. Occasionally rice and maize are added. In a good oat-meal there should be a fair proportion of envelope, but the meal should be devoid of any branny character, which usually arises from barley husks. The starch should not be discoloured, and the whole sample free from *acari*.

RICE.

The whole grain (paddy) deprived of the husk is sold as rice. There are many varieties, of different colours and composition. The amount of nitrogeous matter varies greatly, from 3 to 7·5 per cent. As an article of diet it has the advantage of being an extremely digestible starch grain; it is, however, poorer in nitrogenous substances than wheat, and is much poorer in fat. Consequently, among rice-feeding nations, leguminous seeds are taken to supply the first, and animal or vegetable fats to remedy the latter defect. Rice is also poor in salts.

It is essentially a carbo-hydrate food, and, if properly and sufficiently

cooked, is very digestible. It is best cooked by thoroughly steaming; if boiled in water, it loses some of its protein and saline matter. It cannot be made into bread, but is much used in France for mixing with wheaten flour to make the very white bread which is in request in that country.

The change which raw rice undergoes on keeping appears to play an important part in the etiology of beri-beri. Habitual consumers of "cured" rice, like Indians and Cingalese, suffer less from this disease than do Malays, Siamese, and Japanese, who eat "uncured" rice. The essential difference between the two varieties is that cured rice is boiled and dried before being stored and milled, whereas uncured rice is stored unboiled and unhusked.

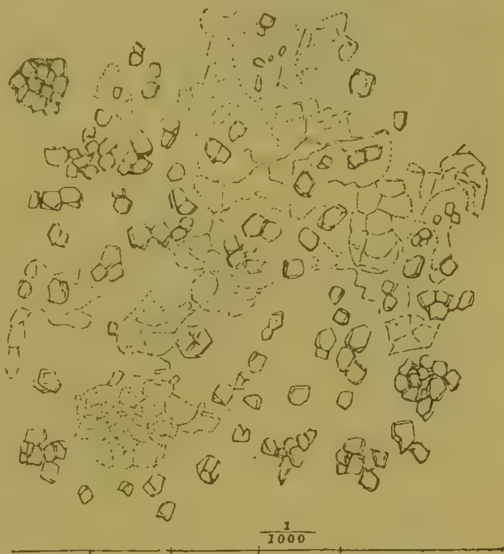


Fig. 39.—Rice Starch Grains.

The starch grains (Fig. 39) are very small, angular under low power, but faceted and compressed under high powers. They cannot be mistaken for the round cells of wheat, but may be confounded with oat starch, from which, however, they are distinguished by the absence of the compound cells or glomeruli. Their shape is also a little like maize, but they are very much smaller.

MAIZE.

Though not much used in England, maize or Indian corn is an important food in America and in Italy, where it is called *polenta*. In its nutritive value, maize resembles oats, containing a large quantity of fat. When made either into cakes or porridge, it affords a valuable food. Maize, being deficient in glutin, does not make good bread; it is, moreover, harsh in flavour. This defect is largely removed by treating it with caustic potash, a procedure which is the foundation of the process for making it into the common commercial articles extensively sold under the names of oswego, corn-flour and hominy. If imperfectly cooked, or at all decomposed, maize may give rise to very disturbing symptoms. The grain, too, is liable to a peculiar disease due to a fungus called *Sporisorium maidis*, which gives rise to a disease in man known as "pellagra," closely resembling scurvy. This affection is not uncommon in Lombardy, where much maize is eaten as food.

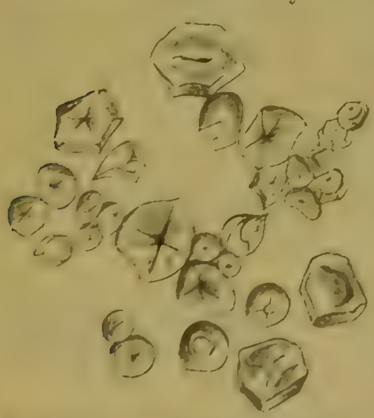


Fig. 40. Maize Starch Grains.

The coats of maize are two, the outer being made up of many strata of cells; there is no transverse second coat as in wheat; the internal coat consists of a single stratum of cells like those in the third coat of wheat, but less regular in shape and size. The cellulose, through the seed holding the starch in its meshes, forms a very characteristic structure, which on section looks like a pavement made of triangular, square, or polygonal pieces; the cells are filled with the starch

grains, which are very small, and compressed, so as to have facets (Fig. 40). They are very different from the smooth, uncompressed round cells of wheat. The starch grains of oats, rice, and maize somewhat resemble each other, since they are all faceted. The maize starch grains are much larger than the other two, with a distinct hilum; oat and rice starch grains are smaller than those of maize, and are usually without a hilum, while both the oat and rice grains have a tendency to collect together into clumps.

MILLET AND BUCKWHEAT.

Various grains belonging to the *Cerealia* or to other natural orders, having similar properties, are used as food in different countries. Of these the chief are the different millets, used largely in Africa, Italy, Spain, Portugal, and some parts of India and China.

English Names.	Botanical Names.	Indian Names.
Common millet	*Panicum miliaceum*	Sanwā Chenawāri (Hindustani). Varagū (Tamul).
Small millet	*Sorghum* or *Panicum vulgare*	Dharrā (Arabic). Cholam (Tamul). Joār or Joārī (Hind.).
Spiked millet	*Pencillaria spicata*	Bājrā or Bājrī (Hind.). Kambū (Tamul).
Golden-coloured millet	*Sorghum saccharatum*	
Italian millet	*Setaria Italica*	Kālā kangnī (Hind.). Tenay (Tamul).
German millet	*Setaria Germanica*	
	Eleusine corocana	Rāgī or Raggy (Hind., Canarese, and Tamul). Murha and Maud in the N. Prov. of Hindustan.

The millets are very similar in composition, their ash being particularly rich in silica and phosphates.

	Water.	Proteins.	Fats.	Carbo-hydrates.	Cellu-lose.	Salts.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Common millet	11·79	10·51	4·26	68·16	2·48	2·80	1 is to 6·89
Small millet	11·46	8·96	3·79	70·25	3·59	1·95	1 „ 8·26
Spiked millet	11·72	8·61	3·54	71·31	3·40	1·42	1 „ 8·69
Golden-coloured millet	15·17	9·26	3·36	67·99	2·51	1·71	1 „ 7·70
Italian millet	12·04	7·40	3·87	74·21	1·37	1·11	1 „ 10·55
German millet	11·92	8·41	3·62	71·50	3·25	1·30	1 „ 8·93
Raggy or Rāgī	13·2	7·30	1·50	73·20	2·50	2·30	1 „ 10·23
Buckwheat	12·68	10·18	1·90	71·73	1·65	1·86	1 „ 7·22

Millet bread is very good, and some was issued to the troops in the last China Expedition. This should always be done in a millet country, if wheat or barley cannot be obtained. In Northern China millet is almost exclusively used.

Raggy or Rāgī (*Eleusine corocana*) is largely used in Southern India and in some parts of Northern Hindustan, and is considered even more nutritive than wheat. It is capable of being preserved for many years in dry grain-pits.

Buckwheat (*Fagopyrum esculentum*) is not so likely to be used. It is poor in nitrogenous substances and fat, and contains a good deal of indigestible cellulose, but it makes fairly palatable cakes.

PEAS AND BEANS.

These belong to the Leguminosæ, and in respect of dietetic properties are broadly distinguished from other vegetable foods by their large amount of nitrogenous substance, called legumin or vegetable casein, which is probably largely derived, during extraction, from certain globulins and albumoses present in these seeds. The character of the proteins in the leguminous plants has not been very well investigated; our fullest knowledge relates to the kidney bean, *Phaseolus vulgaris*, which contains two globulins and legumin. The two globulins, known respectively as *phaseolin* and *phaselin*, are both very soluble in dilute saline solutions, from which they are precipitated by acids, the precipitates being soluble in common salt solution. By prolonged dialysis of their solutions, they separate out and thereby become partially insoluble in brine.

The advantages of peas and beans as articles of diet are the great amount of legumin and salts, especially those of potash and lime. Their disadvantages lie in their great indigestibility and poorness in fat and sodium chloride. Rubner has shown that from about 21 to 30 per cent. of the nitrogen of peas passes out undigested in the fæces as compared with 13 to 14 per cent. of the nitrogen of white bread, and about 17 per cent. of black bread. The existence of sulphur frequently causes flatus from the production of hydrogen sulphide. Still they are a most valuable article of food, and always ought to be used when much exercise is taken, as they constitute an excellent addition to meat and the other cereals. Both men and beasts can be nourished on them alone for some time; in fact, added to rice, they form the staple food of large populations in India.

Fig. 41.
Pea and Bean Starch Gr ins.

Closely allied to peas and beans are Lentils (*Ervum lens*), Gram (*Phaseolus Mungo*), Soja beans (*Soja hispida*), Lablab beans (*Dolichos lablab*), and Dal (*Lathyrus sativus*). Lentils contain a large amount of protein, are rich in iron and phosphate of lime, and have the advantage over peas of containing no sulphur. "Revalenta" is prepared from lentils. Gram, although chiefly used for horses and cattle, is sometimes employed as food for men in India, making palatable and nutritious cakes. Soja or Soy beans, from the large amount of fat they contain, approximate in composition to the oily seeds, such as linseed, pea-nuts, walnuts, hazel-nuts, and almonds. Lablab beans are obtained from a pulse grown in India, not only for its ripe seeds, but also for its green pods, which are used as a vegetable. The Dal is a vetch used occasionally in Europe and constantly in India, when mixed with wheat or barley flour, for bread. When used in too great quantities, it produces constipation, colic, and indigestion. It is also injurious to horses, but less so to oxen. To this group belong also the seeds of the Peruvian food, the *Chenopodium Quinoa*. The starch grains of the Quinoa are said to be the smallest known. It may be worth remarking that this seed is very rich in salts (2·4 per cent.), and particularly so in iron (0·75 per cent.); indeed, it is the richest in iron of any vegetable. It is possible that it might be a useful food in some cases of illness. It is fairly nutritious and digestible. The Table on page 320 shows the percentage composition of some of the more common leguminous seeds:—

	Water.	Protein.	Fat.	Carbo-hydrate.	Cellu-lose.	Salts.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Pea flour	11·41	25·20	2·01	57·17	1·32	2·89	1 is to 2·3
Green peas	78·44	6·35	0·53	12·00	1·87	0·81	1 „ 1·8
Dried peas	13·92	23·15	1·89	52·68	5·68	2·68	1 „ 2·2
Bean flour	10·29	23·19	2·13	59·37	1·67	3·35	1 „ 2·6
Dried beans	13·49	25·31	1·68	48·33	8·06	3·13	1 „ 1·9
Fresh French beans	88·75	2·72	0·14	6·60	1·18	0·61	1 „ 2·4
Haricot beans	11·24	23·66	1·96	55·60	3·88	3·66	1 „ 2·4
Lentil flour	10·73	25·46	1·83	57·35	2·01	2·67	1 „ 2·3
Gram	10·80	22·20	2·70	54·10	5·80	4·40	1 „ 2·7
Soja beans	15·70	33·40	17·70	26·00	3·10	4·10	1 „ 1·2
Lablab beans	12·10	24·40	1·50	57·80	1·20	3·00	1 „ 2·5
Lathyrus sativus	12·74	24·08	2·38	51·38	6·60	2·82	1 „ 2·2
Yellow lupin seeds	13·98	38·25	4·38	25·46	14·12	3·81	1 „ 0·8

It will be noticed how great is the difference between the composition of fresh and dried peas; roughly, 1 part of the dried pea equals, by weight, 4 parts of the green in proteins and carbo-hydrates.

The starch grains of peas and beans (Fig. 41) are characteristic, being oval or kidney-shaped; they have no clear hilum, but usually a deep central longitudinal cleft, or at times an irregularly shaped depression. The addition of hot water to pea or bean flour causes the emission of the typical beany smell. Pea flour is sometimes met with as an adulterant of wheat flour, but rarely to a greater extent than 4 per cent., as it makes the bread heavy and dark.

POTATOES.

These may be considered as occupying a place next in importance to the seeds of the cereals as articles of vegetable food. The potato, used as food, is the tuber or exuberant growth of a portion of the underground stem of the *Solanum tuberosum*. The tuber develops into a thick fleshy mass, retaining its buds under the name of "eyes," each of which is capable of independent growth when in a detached or isolated state. In its chemical composition the potato shows a large proportion of starch with a very small quantity of protein. The juice of the potato is acid, due to the presence of a certain amount of free citric acid with citrates of potassium, sodium, and calcium. In dietetic value, the potato is both a carbo-hydrate, and an anti-scorbutic. As the amount of salts is small, and that of water large, at least 8 to 12 ounces of potatoes should be taken daily, if no other vegetables are eaten.

Fig. 42.
Potato Starch Grains.

The starch grains of the potato (Fig. 42) are characterised by being large oyster-shaped granules with well-marked concentric rings, and a clear though small hilum at the narrow end. Weak liquor potassæ (1 in 10) swells them out greatly after a time, while wheat starch is little affected by this strength. Potato starch is largely used for adulterating the more expensive farinaceous dietetic preparations; though cheaper, there is nothing to show that potato starch is less nutritious than other starches.

Potatoes require to be cooked before being eaten; this may be done by

either steaming, boiling, baking, or frying. The heat coagulates the albuminous juices, and the absorbed water swells up and distends the starch grains. When these changes are complete, the potato is said to be mealy or floury; when these changes are only partially completed, and the starch cells imperfectly broken up and separated, the potato remains more or less firm, and is spoken of as being close, waxy, or watery. The potato plant is sometimes affected with a fungus—the *Phytophera infestans*—which causes the disease known as potato murrain. This can readily be detected by the microscope. The disease commences in the leaves of the plant, and thence extends to the stem and on to the tubers. On the surface of the latter, brown spots make their appearance, penetrate the potato, and eventually cause it to rot and decay.

The quality of the potato is usually judged by its size, firmness, and absence of fungus disease.

The Sweet Potato and the Yam are somewhat similar to the ordinary potato, and form good substitutes when potatoes cannot be obtained. They are very rich in salts, and are therefore excellent anti-scorbutics.

As judged by their composition, *Beetroot* and *Jerusalem artichoke* are closely allied to the potato, but as foods they are of very subsidiary importance. The relative percentage composition of these vegetable foods is shown below:—

	Protein.	Fat.	Carbo-hydrate.	Salts.	Cellu-lose.	Water.	Ratio of nitrogenous to non-nitrogenous food-stuffs.
Potatoes . . .	2·00	0·16	21·00	1·00	0·70	75·14	1 is to 11·43
Beetroot . . .	1·15	0·10	14·35	0·73	0·91	82·76	1 ,, 10·6
Jerusalem artichoke .	1·76	0·14	16·29	1·08	1·49	79·24	1 ,, 10·8

Young unripe potatoes, and also those which have been kept too long and are sprouting, contain solanin, especially in the skin and in the shoots. Ripe potatoes which have reached their full size are either very poor in solanine, or totally free from this alkaloid. There is reason to believe that the poisonous character of solanin in potatoes is largely exaggerated, and that the diseases of cattle ascribed to the consumption of solaniferous potato waste from distilleries have been partly infectious diseases and partly poisonings from ptomaines. Potatoes are further said to lose the chief part of their solanin by boiling. On keeping, there ensues in the potato a slow decrease of the starch, which passes temporarily into dextrin, and in small quantities into sugar. Kramer has recently described a bacillus, nearly allied to the *B. butyricus*, as the cause of the wet-rot in potatoes. If the spoiled parts are cut away, the remainder may be eaten without injury; the decayed part tastes and smells badly. Frozen potatoes are often destroyed by putrefaction after thawing, but before they putrefy they are not hurtful to health. Tubers bared of soil become dark coloured next the stem; their pungent taste is said to be due to solanin.

ARROWROOTS, TAPIOCA AND SAGO.

The arrowroots are obtained from various sources. Originally, the term arrowroot was applied to the starch from the tuber or rhizome of the *Maranta arundinacea*, because that root was supposed to have the power of counteracting the effects of poisoned arrows. The term is now applied to a

great variety of starches, but, strictly speaking, should be limited to those known in commerce as Canna, Curcuma, Maranta, and Tacca arrowroots. The roots of the plants are dug up when about a year old, washed, and reduced to a pulp. This is repeatedly washed, passed through coarse sieves to separate the fibres, and the starch allowed to settle, which again is washed and dried. When finished and ready for exportation, arrowroot is a white, tasteless, odourless substance, firm to the feel, and producing, on pressure, a slight crackling noise. Arrowroot, being a pure starch, has no dietetic value beyond that peculiar to this substance. It is chiefly used as a bland article of food for invalids, or, in an ordinary way, as blancmange, puddings, and biscuits.

Fig. 43.—Bermuda Arrowroot Starch Grains.

Maranta arrowroot, sometimes spoken of as Bermuda arrowroot (Fig. 43) is derived from the *Maranta arundinacea*, a plant growing in Jamaica and Bermuda. It is judged by its whiteness, by the grains being aggregated into little lumps, and by the jelly being readily made, and being firm, colourless, transparent, and of good flavour. The jelly remains firm for three or four days without turning thin or sour, whereas potato-flour jelly in twelve hours may become thin and acescent. Under the microscope the starch grains are easily identified. They are slightly ovoid, like potato starch, but have a mark or line at the larger end (the hilum of the potato starch is at the smaller end); the concentric lines are well marked. The most common adulterations are sago, tapioca, and potato starch. All these starch grains are readily detected by the microscope.

Fig. 44.—Curcuma Arrowroot Starch Grains.

The starch grains of *St. Vincent* arrowroot have the same character as those of Bermuda arrowroot, and it is almost impossible to distinguish them.

Curcuma arrowroot is furnished from the *Curcuma angustifolia*, a species of turmeric plant. Its starch grains under the microscope are large and oblong (Fig. 44), marked with very distinct concentric lines, which, however, in the majority of cases, are not complete circles. The hilum is often indistinct and always at the smaller end.

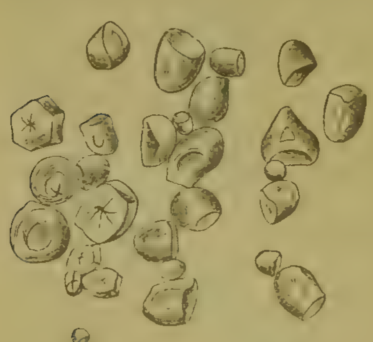


Fig. 45.—Tacca Arrowroot Starch Grains.

Tacca arrowroot is obtained from the *Tacca oceanica*, growing in Tahiti. Its granules are truncated, or wedge-shaped at one end. Their striation is indistinct with a more or less circular hilum. These starch grains are practically indistinguishable from those of Rio arrowroot (Fig. 45) obtained from *Jatropha manihot* or *Cassava* growing in the Brazils. It is from the finest part of the pith of this plant that commercial tapioca is made. Tapioca is often adulterated with potato starch and sago, both of which are easily detected by the microscope.

Canna arrowroot or "Tous-les-Mois" (Fig. 46) is furnished by the *Canna edulis*, a native of the West Indies. Its starch grains are very like those of potato, but they are much larger, flatter, and have more definite striæ. The hilum is at the smaller end of the grain.

Sago is derived from the sago palm, *Sagus farinifera*, but some inferior kinds are obtained from the *Cycas circinalis*. The starch grains are very similar to those of tapioca, but larger (Fig. 47).

Granulated sago is either "common" or "pearl"; the latter is chiefly used in hospitals. The starch is soluble in cold as well as in hot water. The starch grains are elongated, rounder at the larger end, and compressed at the other; and hence their shape is quite different from the potato starch. The hilum is a point, or more often a cross, slit, or star, and is seated at the smaller end, whereas in Maranta arrowroot the hilum is at the larger end. Rings are more or less clearly seen.

In the market is a fictitious sago made of potato flour. This is sometimes coloured red or brownish, either from cochineal or sugar. In thirty

Fig. 46.—Canna Arrowroot Starch Grains.

Fig. 47.—Sago Starch Grains.

specimens Hassall found five to be spurious. The microscope easily detects potato starch.

Under the name of British arrowroot or "Farina," potato starch is sold in the market, so white and crackling, and making so good a jelly, that it is not always easy to distinguish it from *Manihot*. The microscope at once detects it. The pear-shaped grains, marked hilum towards the smaller end, and the swelling with weak liquor potassæ, render a mistake impossible. In making the jelly a much larger quantity is required than of Maranta arrowroot. *Maranta arundinacea*, mixed with twice its weight of hydrochloric acid, produces a white opaque paste, whereas potato starch treated similarly produces a transparent acid jelly-like paste.

As it is sometimes difficult to remember the characters of the different forms of starch, their microscopical differentation may, to a certain extent, be facilitated by a tabulated arrangement (*see* page 324).

I. *Starches* with isolated smooth or unfaceted grains, being originally free in the cell cavity.

	General Characters.		Particular Characters.		Name.
	Form.	*Hilum.*	*Form.*	*Hilum.*	
Unfaceted.	A.—Contour ovoid. *Hilum* eccentric.	Grains large. *Hilum* at the small end.	Outline even. Continuous rings, oblique, including more than half the grain.	*Hilum* distinct.	Potato; British arrowroot.
			Outline even. Continuous rings, nearly transverse, including less than half the grain.	*Hilum* distinct.	Tous-les-Mois (*Canna*) arrowroot.
				Hilum indistinct.	*Curcuma* arrowroot.
		Grains medium sized. *Hilum* at the larger end.	Outline uneven, often with beak-like projections.	*Hilum*, slit-like, triradial or crucial.	Bermuda (*Maranta*) arrowroot.
			Outline more even, beak less frequently seen.	*Hilum* similar, but less apparent.	St. Vincent arrowroot.
	B.—Contour oval.	*Hilum* longitudinal, linear lateral.	Grains often broad and reniform.	*Hilum* cleft-like, puckered, irregular.	Bean starch.
			Grains narrower and more uniform.	*Hilum* less puckered and more regular.	Pea starch.
	C.—Contour round.	*Hilum* central.	Form lenticular.	Surface convex at the *hilum*. Grains large and minute only.	Wheat starch.
				Surface depressed at the *hilum*. Grains large, medium-sized, and minute.	Barley starch.
			Form spherical.	*Hilum* often deeply fissured, star-like.	Rye starch.

II. *Starches* with the grains faceted by original juxtaposition in the cell cavity. *Hilum* central.

Faceted.	A.—Often presenting the rounded free surface of grains originally superficial in the cluster.	*Hilum* often cavernous.	Grains very large, with a central sinus or cavernous antrum. (Rings, sinuous, irregular.)		Sago.
			Grains small. (Sago in miniature.)		Tapioca.
		Hilum stellate.	Grains small. (Like Tapioca without preparation.)		Rio arrowroot.
	B.—Altogether faceted.	*Hilum* stellate.	Grains small. (Discoidal with faceted margin.)		Maize.
		Hilum inconspicuous.	Grains minute.	In rounded glomeruli or compound grains, and free in the cells.	Oats.
				Closely packed in the cells and fixed.	Rice.

SUGAR.

There are two chief varieties of sugar now found in the market, namely, sugar from the sugar-cane, *Saccharum officinarum*, and beet-sugar from the *Beta vulgaris*.

Cane-sugar is either white or brown. The white cane-sugar contains, per cent., 93·33 of saccharose, 1·78 of dextrose, 0·35 of protein, 0·30 of gum, 0·91 of so-called extractives, 0·76 of salts, and 2·16 of water. Brown sugar contains more water than the white, the amount varying from 4 per cent. in the better kinds to 10 per cent. in the coarser varieties. Its colour is due to invert sugar, of which there is 4 or 5 per cent. present.

Beet-sugar contains, in 100 parts, 94·5 of saccharose, 0·18 of invert sugar, 1·93 of water, and 3·37 of extractives, gums, and vegetable acids.

Honey differs from ordinary sugar in containing more dextrose and lævulose than saccharose. Its precise composition varies very much, but, on an average, it may be said to have, in 100 parts, 72·88 of invert sugar (lævulose 38·65, dextrose 34·23), 0·22 of dextrin, 1·76 of saccharose, 0·71 of wax, 0·76 of protein, 2·82 of non-saccharin substances, 0·25 of ash, 0·028 of phosphoric acid, and 20·6 parts of water. Honey is often adulterated with cane-sugar, with sugar made from starch or with inert matter (Martin). The total invert sugar may be as high as 80 per cent., or as low as 64, but the lævulose is always in greater proportion than the dextrose.

Examination of Sugar.—Sugar should be more or less white, crystalline, not evidently moist to the touch, and should dissolve entirely in water, or leave merely small fragments, which, on examination with the microscope, will often be found to be pieces of cane. The whiter the sample, the less usually is the percentage of water. The unpurified sugars contain nitrogenous matters which decompose, and fermentation occurs. The sugar-mite is often found in such sugar, while fungi are very frequently present. The actual amount of sugar present in a sample may be conveniently estimated by dissolving 5 grammes in distilled water and making up to 100 c.c. Of this solution, 10 c.c. are diluted to 100 c.c. with water, and from 1 to 2 c.c. of hydrochloric acid added. Boil away one-third of the volume, cool, neutralise with sodium carbonate, and then make up to original bulk of 100 c.c. Titrate copper solution, as used for lactose, with this solution of inverted sugar and calculate out as a percentage of cane-sugar; each c.c. of the copper solution equalling 5 milligrammes of inverted sugar.

Saccharin.—In this place it is convenient to mention saccharin (orthobenzoic sulphinide) which has appeared in the trade as a white inodorous powder, three hundred times as sweet as cane-sugar. Pure saccharin is sparingly soluble (1 in 260) with a faint acid reaction, but lately an alkaline salt has been introduced which is more readily dissolved. Its taste is slightly aromatic, and its after-taste irritating only when the powder itself, or a concentrated solution, is tasted; dilute solutions have a purely sweet flavour. Saccharin is recommended as a substitute for cane-sugar. As 2 grains of saccharin suffice to give 1000 grains of starch-sugar the same sweetening power as that of 1000 grains of cane-sugar, it is likely that substitutions of a cheaper for a more expensive material will be attempted in this direction.

The detection of saccharin may be effected by extracting the dried substance with anhydrous ether; if the evaporated residue have a sweet taste, saccharin is present, all sugars and also glycerin being insoluble in ether.

According to the experiments of all observers, saccharin is non-poisonous, even in continuously large doses; but since it has no nutrient properties, its substitution for a carbo-hydrate reduces nutritive value. A substitution of pure starch-sugar, sweetened up with saccharin for an equal weight of cane-sugar, cannot be regarded, physiologically speaking, as an injury. If the use of saccharin is thus hygienically unobjectionable, a declaration of its presence should be unconditionally demanded. The antiseptic and antizymotic properties of saccharin have no practical value.

SUCCULENT VEGETABLES AND FRUITS.

This class of vegetable food contains articles of diet which supply water, vegetable acids, and salts to the body. Their chief value depends upon their anti-scorbutic properties, as their absence for any lengthened period from a diet leads to the production of scurvy. To all succulent vegetables, common salt is added in cooking; and to some, butter is a valuable addition. The fruits are rich in water, vegetable acids, and salts of the organic acids; they are eminently anti-scorbutic, especially the lemon. Some, like the cocoa-nut, are rich in oil, while others, like the banana, contain large quantities of sugar. Except for their anti-scorbutic properties, and pleasant taste, the fruits are quite subsidiary as articles of diet. The percentage compostion of some ordinary vegetables and fruits is given in the following table:—

	Water.	Proteins.	Fat.	Starch.	Glucose.	Cellulose.	Salts.	Malic Acid.	Oxalic Acid.	Pectose and Gum.	Citric Acid.
Cabbage	85·50	5·00	0·50	7·80	—	—	1·20	—	—	—	—
Carrots	87·80	1·00	0·20	9·60	0·40	—	1·00	—	—	—	—
Cauliflower	90·89	2·48	0·34	3·34	1·21	0·91	0·83	—	—	—	—
Celery	93·30	1·20	—	1·60	2·20	0·90	0·80	—	—	—	—
Lettuce	96·00	0·70	0·20	1·00	—	0·50	1·00	—	—	—	—
Spinach	88·47	3·49	0·58	4·34	0·10	0·93	2·09	—	—	—	—
Turnips	90·78	1·18	0·22	5·89	—	1·13	0·80	—	—	—	—
Rhubarb	95·10	0·90	—	—	2·10	1·10	0·50	—	0·30	—	—
Apples	83·00	0·40	—	—	6·80	3·20	0·40	1·00	—	5·20	—
Dates	20·80	6·60	0·20	—	54·00	5·50	1·60	—	—	12·30	—
Gooseberries	86·00	0·40	—	—	7·00	2·70	0·50	—	—	1·90	1·50
Figs	17·50	6·10	0·90	3·00	57·50	7·30	2·30	—	—	5·40	—

Vegetables scarcely require any very critical hygienic examination; if they have become too old and woody, they are inferior in nutritive value, and are imperfectly digested; stale vegetables are equally inferior in value and far from appetising. If vegetables are watered with sewage or drainage containing certain parasites, the latter may find their way into man; pathogenic bacteria may possibly be introduced in the same way; in fact, there is reason to believe that in this manner watercress, growing in sewage-polluted streams, has been on several occasions the source of enteric fever outbreaks.

According to Lominsky, various bacteria penetrate into the roots of young plants but do not increase there. Some pathogenic species, if inoculated into living leaves, are said not merely to maintain themselves, but even to multiply. These observations, however, require verification. De Loos has recorded a remarkable instance of lead-poisoning from vegetables being grown upon soil over some disused white-lead works. He states that 650 grammes of turnips had absorbed 10 milligrammes of lead, six

carrots 17 milligrammes; and four lettuces had taken up as much as 130 milligrammes of lead.

Frequently cases of poisoning arise from mistakes as to the identity of vegetable species. Thus fool's parsley (*Æthusa cynapium*) is mistaken for true parsley, water hemlock (*Cicuta virosa*) for celery, and *Œnanthe crocata* for carrot.

Dried vegetables are now produced of excellent quality, and when properly prepared taste as if fresh. They appear to present no special points for hygienic criticism.

Unripe fruit, rich in cellulose, acids, and in tannin, but poor in sugar, often occasions intestinal catarrh. The popular characteristics of ripeness should suffice for an experienced observer. For stone fruits and berries, the colour, consistence, and taste should be noted; in the case of seed fruits, such as apples and pears, it is advisable to examine whether the pips have taken a brown colour. Mouldy fruit should invariably be rejected. Dried fruits often require examining for dirt, sand, mould, and mites. In some specimens of American tinned fruit a small proportion of zinc has been detected.

Among the fruit juices, currant and cherry juice are of less interest than raspberry. The juices are attempted to be obtained from the pressed and sweetened fruits partly by boiling, and partly by fermentation. Frequently the colour suffers by unsuitable preparation or preservation, and is artificially heightened by vegetable colours, such as that from infusions of the field poppy, or more commonly by means of aniline dyes. There is no objection to the use of these latter if employed in small quantities and provided they are free from arsenic and other impurities.

Mushrooms and the fungi generally, in spite of the high percentage of nitrogen in their solids, do not rank higher in nutritive value than the majority of vegetables. Like the latter, they yield an edible food only in presence of much water; their nitrogen is largely referable to worthless amido-compounds, while the utilisation of their albumin is imperfect.

There are no general characters for the recognition of edible fungi. It must be borne in mind that the virulence of many poisonous kinds varies according to the year and locality. It is obvious that of the kinds known as wholesome, only such specimens must be gathered as are fresh, not decayed or damaged by rain. All mushrooms must be carefully cleaned before use. It is not advisable to preserve portions of dishes of mushrooms which have not been consumed. The use of dried mushrooms is as far as possible to be avoided; the species are seldom correctly determined, and they are often imperfectly cleaned, dusty and perforated by insects.

CONCENTRATED, PREPARED AND PRESERVED FOODS.

This is a very important subject, but one upon which considerable misconception exists, owing to a confusion of ideas between concentration and preservation. Further, it is necessary to discriminate between simple concentration and artificial preparation of food, because a number of foods are now on the market, which, being neither fresh nor preserved, are designed either to present a maximum of nourishment in a minimum of bulk, or to facilitate the enriching of a diet in respect of certain of its chemical constituents.

In regard to the former of these objects, it is necessary to realise that there are definite limitations to the degree of concentration of a food. We see this when we consider the constituents of food. Meat, for instance, contains 20 per cent. of protein, the rest consisting of water with a little

mineral matter and fat. If we drive off the water from the meat, we get left what is practically nothing but protein, amounting in weight to one-fifth of the original whole; and it is impossible to get protein in a more concentrated form than this. If we want carbo-hydrate, we can get no more concentrated carbo-hydrate food than sugar, because it is practically free from water and it contains no added ingredients. Again, if we want fat, we can find no more concentrated form of fat than oil, which is a natural food; similarly, few preparations are richer in fat than ordinary butter.

Setting aside such important details as digestibility or cheapness, we find that in respect of compactness alone there are definite physical limitations, and that concentrated foods are only to be regarded as accessories.

If we attempt to classify the concentrated and artificial or prepared foods we find some difficulty, but probably the simplest and most logical classification is that which divides them into those (*a*) of animal origin, (*b*) of vegetable origin, (*c*) of both animal and vegetable origin. In such a classification, no attempt is made to differentiate between what is merely a natural food concentrated and what is an artificially prepared food.

Among foods of this kind of animal origin are the various meat extracts, meat juices and meat powders, as well as such artificial protein foods as pemmican, biltong and charqui; also the various milk preparations derived from casein, such as plasmon, casumen, nutrose, eucasin, protene, sanatogen, &c. Of those having a purely vegetable origin, the more prominent are aleurone, legumin, plantose, roborat and the malt extracts. As typical of those having a mixed origin, we may mention erbswurst, tropon, meat biscuits and certain army rations.

Meat Extracts.—In the ordinary sense of the term, these are of very little, if any, food value. They contain little protein; what they contain chiefly are the extractives and mineral salts of meat. Experiment shows that the extractives are only of use in so far as they stimulate appetite; they are not foods and hardly true stimulants. The nearest approach to giving a food value to a meat extract is the case of Bovril, in which meat fibre is added to the extractives and salts. But even in this case the food value is small, being in fact such that a teaspoonful of Bovril is only equivalent to a piece of lean meat weighing one-fifth of an ounce, or say about half a cubic inch in size. To the extract group belong such preparations as Hipi, Lemco and the various essences.

Meat Juices come under a different heading from the extracts, because they contain the fluid protein of meat in an uncoagulated form. Prominent members of this group are Puro, Bovinine, Vinsip and Leube-Rosenthal's meat solution. The first three are probably blood preparations, and of them Puro also contains egg albumin. The percentage composition of some well-known meat extracts and meat juices is given below:—

	Water.	Protein.	Gelatin.	Extractives.	Mineral Matter.	Ether Extract.
Lemco	18·3	9·4	—	30·0	23·6	18·6
Bovril	44·4	16·94	—	20·32	18·32	—
Armour's Extract	15·55	8·73	2·16	43·23	25·91	4·12
Brand's Essence	87·17	5·40	5·03	1·01	1·39	—
Puro	36·60	30·33	—	19·16	9·79	—
Bovinine	81·09	13·98	—	3·40	1·02	—
Valentine's Meat Juice	51·21	9·65	—	11·16	10·84	—
Wyeth's Meat Juice	44·87	15·01	—	23·00	17·12	—
Armour's Beef Juice	74·10	8·3	—	9·54	7·51	—
Brand's Beef Juice	59·15	15·45	—	16·55	8·85	—

Meat Powders.—A variety of these preparations exist, and are merely meat, after the water has been driven off, reduced to a fine meal. Among the more prominent of these are Sanose, Mosquera Beef-meal and Somatose. All are highly nutritive, and the meat has undergone partial digestion. Closely allied to the meat powders is a preparation of dried meat called pemmican, the nutritive value of which has been raised by the incorporation of 40 parts of fat with every 50 parts of powdered meat, with the result that it is bulk for bulk about the most nourishing food known. Dried meat in the form of the South African biltong * or the South American charqui are other examples of this class of preparation.

Peptone Preparations.—There exists a large number of food-stuffs which come under this category. Their value is probably exaggerated, one great defect in them being the fact that if consumed in anything like large quantities they are apt to excite diarrhœa. The percentage composition of some of the better ones are given in the accompanying table. In both Carnrick's and Fairchild's preparations much of the non-protein organic matter is sugar.

	Water	Soluble Proteins, chiefly Albumoses.	Extractives and other Non-protein Organic Matter.	Mineral Matter.
Brand's Beef Peptone .	84·6	7·0	—	1·4
Liebig's Peptone . .	31·9	33·4	24·6	9·9
Koch's Peptone . .	40·16	34·78	15·93	6·9
Denaeyer's Peptone . .	78·45	12·15	4·32	2·5
Carnrick's Peptonoids .	5·4	24·0	65·4	5·2
Darby's Fluid Meat .	25·7	30·6	30·2	13·5
Fairchild's Panopepton .	81·0	3·0	15·0	1·0

Milk Preparations.—This is a large group in which the protein of milk—casein—has been separated out in a pure form. Casein has the advantage of being tasteless, colourless and odourless; it is free from nuclein, and on that account is well tolerated by the gouty. A large number of preparations of casein have been introduced under special names: such as plasmon, in which the casein is rendered soluble by the addition under special conditions of bicarbonate of sodium; nutrose, which is sodium casein; eucasin, which is ammonia casein; protene, and a number of others. They all contain from 80 to 90 per cent. of protein and are probably some of the most all-round useful of the artificial foods.

Vegetable Preparations.—The majority of these aim at supplying protein and are well represented by aleuronat, legumin, roborat, plantose, and such articles as marmite and the various malt extracts. Aleuronat is a special preparation of glutin, containing 85 per cent. of protein; it is fairly cheap, but insoluble. Legumin or vegetable casein is bitter in taste and derived from the pulses. Roborat is derived from various cereals and contains 83 per cent. of protein. Plantose is a similar vegetable protein obtained from rape-seed. Marmite is a good example of an increasing number of extracts prepared from yeast. They resemble closely the meat extracts in their general characters, so much so that it is very difficult to distinguish them.†

Hehner has pointed out that a true meat extract contains about 11 per

* Halliburton: "The Composition and Nutritive Value of Biltong." *Brit. Med. Journal*. April 26, 1902.

† For methods of distinguishing yeast extracts from true meat extracts, see papers by A. Searl in the *Pharmaceutical Journal*, October 10 and November 14, 1903.

cent. of kreatin, and the differentiation of meat extract from yeast extract may be based on the fact that the former contains kreatin *plus* kreatinin, while the latter contains, practically speaking, neither of these bodies. Kreatinin yields, when heated with alkaline picrate, a blood-red coloration due to the formation of kreatinin picrate. Kreatin does not act in this way until it is first heated with dilute hydrochloric acid, which converts it into kreatinin. The coloration can be imitated by operating on a definite quantity of a standard solution of pure kreatinin, and by colour comparison an estimation be made as to the amount in a given preparation. The main point to be observed in this method is to ensure that the picric acid is in excess or more than sufficient to combine with all the kreatinin present. Otherwise, the results will be irregular and below the real figure. Owing to their richness in purin bodies, these yeast extracts are harmful for the gouty. A sample of Marmite which came under our notice yielded 26 per cent. of water, 37 per cent. of extractives, 11 per cent. of proteins, and 27 per cent. of mineral matter. The kreatin figure was 1·76 per cent., indicating that the preparation contained some 16 per cent. of extract of meat, sufficient to make it present the appearance and smell of a true meat extract. We believe these yeast extracts to possess similar dietetic properties to genuine meat extracts, but they are not extracts of meat any more than margarine is butter. It is desirable that they be described honestly.

The next sub-group includes certain foods intended specially to supply carbo-hydrates. The best examples are the malt extracts. They contain roughly, as a percentage, sugar 55, soluble starch 15, proteins 6, and ash 2. These preparations appear to be very popular, but why, it is difficult to understand. Their primary dietetic object should be to supply diastase as an aid to digestion of starch, but it is doubtful whether many are sufficiently well prepared to present this ferment in an active state. If they are popular as a source of sugar, then they are very extravagant, and far inferior to honey.

Prepared Foods of Mixed Origin.—This is a very extensive group and contains foods of the most diverse taste, appearance and origin, ranging from simple tropon, through the various meat biscuits and pease sausages, to the more complex preparations of the so-called "emergency" or army ration type. Tropon is a protein food derived from both animal and vegetable sources. It is a brownish insoluble powder, free from taste, made chiefly from fish and cheap vegetables. Three-quarters of an ounce of it contains as much protein as 4 ounces of raw beef. The majority of meat biscuits are as a rule nothing but meat powders mixed with flour and water. Owing to the extreme heat to which they are exposed in baking, the meat in them is rendered more or less valueless. A large number of them have come under our notice, for army requirements, but the majority have failed to present any very distinctive points of merit.

The original Erbswurst of the Germans was a sausage of pease with bacon fat. Numerous preparations of this kind are now in the market; they consist in the main of powdered pease with bacon or beef fat and condiments, the whole being enclosed in a waterproof cover, and then issued as a sausage or packet. Some few also contain powdered beef. The nutritive value of the several kinds is practically 18 per cent. of protein, 23 per cent. of fat, 36 per cent. of carbo-hydrate, 12 per cent. of salts, and 11 per cent. of water. Erbswurst soon becomes distasteful, causing digestive derangements from its excess of fat; it at the same time lacks the sustaining qualities of fresh meat.

The pea-soup tablets of Neumann are made of meat juice with pea flour.

Their relatively high amount of salts is said to be due to sodium chloride. It would be necessary to take 21 ounces of this preparation to get the daily need of 100 grammes of protein, at the same time, one would obtain only 16 grammes of fat and 307 grammes of carbo-hydrate, which are insufficient. A similar defect is present in the pease and haricot cakes of Schorke, and the meat cakes of König of Mayence. Rumfords' ration contains pieces of meat with flour, pearl barley, and salt. Like Schorke's preparations, it does not constitute a complete aliment. Edward's desiccated soup was well spoken of in our own army during several campaigns. It consists of a mixture of beef and vegetables and is prepared easily by boiling an ounce of the powder in a pint of water. Allusion may here be made to "parrole," which is a preparation made of ground, parboiled Indian corn 3 parts, and sugar 1 part; at one time this was largely used in the frontier expeditions of the American army.

An English and at the same time a very good preparation is Morel's field ration, sold as a sausage, weighing 18 ounces. Equally good articles are Moir's sausage and Corbin's pea and lentil pastes. In all this class of prepared or emergency rations we find a marked excess of fats and carbohydrates. The salts are variable, though in all cases much in excess of the meat quantities. Although these preparations yield the alimentary elements of a complete food, yet they are in such proportion as only to serve as food for a limited time. Further, in most of them the albumin is vegetable, being derived from peas and beans. It is true the chemical values of animal and vegetable albumin are the same, yet experience shows the former to be very much more easily and completely assimilable than the latter.

Of all the prepared foods, the army rations made by Moir, Maconochie, and other makers appear best to conform to the ideal type of an emergency ration. They exist in several varieties, consisting of mixtures of either beef or mutton, with potatoes, carrots, onions, beans, gravy, and pickles. Some also contain bacon fat and brawn, the whole being cooked and contained in hermetically sealed tins of small size, and may be eaten either cold or warmed up. "Maconochie's patent army ration" consists of $\frac{3}{4}$ lb. meat and $\frac{1}{2}$ lb. vegetables and gravy put up in a tin—gross weight 1 lb. 13 ounces. The present "emergency ration" for use on active service consists of a small tin cylinder divided into two compartments and weighing 12 ounces. Both compartments are equal in size; one contains 4 ounces of concentrated beef (Pemmican), and the other 4 ounces of cocoa paste. These preparations can be eaten in their semi-solid form, or they can be made into 4 pints of soup and 4 pints of cocoa.

Among other preparations of this class may be mentioned Sarxcene, suggested by Yorke Davis; this is a highly nutritious food made of meat and flour; it contains 31·4 per cent. of protein and 10 per cent. of fat. A tropon ration, in which there was evidently a considerable element of potato, gave on percentage analysis 22 of protein, 20 of fat and 38 of carbo-hydrate. Carnyl, made by Maconochie, is a pink-coloured material looking like sausage-meat, made up in 1 lb. packages. We found this very palatable, but like the tropon-potato ration too rich in fat to be consumed daily. The Armour Packing Company's army ration contains 4 ounces of chocolate in one compartment and 12 ounces of a mixture of minced meat and shredded wheat in the other. The whole ration yielded 118 grammes of protein, 39 grammes of fat, 260 grammes of carbo-hydrate, or an energy value of 1915 Calories. A special service emergency ration made by the Bovril Company, consisting of $3\frac{1}{2}$ ounces of meat powder with 4 ounces of chocolate paste, the whole being made up in a tin case divided into two distinct parts, yielded

53 grammes of protein, 70 grammes of fat, and 82 grammes of carbo-hydrate, representing roughly 1200 Calories. The same company's "blue ration," consisting of $2\frac{1}{2}$ ounces of chocolate in one half, and 5 ounces of coarsely chopped-up cooked meat and vegetables in the other, yields 42 grammes of protein, 33 grammes of fat, and 71 of carbo-hydrate, or 770 Calories; their "red ration" of chocolate and meat powder made up in a similar way has an energy value of 860 Calories. The present service emergency ration, consisting of 4 ounces of chocolate paste in one section of a tin cylinder, and 4 ounces of pemmican in the other, yields 49 grammes of protein, 27 grammes of fat and 107 grammes of carbo-hydrate, or a total energy value of 890 Calories.

In judging the merits or demerits of this class of aliment, it must be borne in mind that not only must their nutritive value be taken into account, but also their portability, durability, palatableness and readiness for cooking. Few of these made-up rations yield more than 800 Calories for each $\frac{1}{2}$ lb. in weight. Those that have a higher potential energy value generally obtain it from a relative richness in fats, a feature which is detrimental to their practical utility. In all this class of ration we are disposed to think that the essential feature should be that of the total energy available from such foods, at least one-fourth should be from protein. On the whole it must be confessed that this question of preparing emergency foods has not been yet satisfactorily solved; much remains still to be accomplished.

Preserved Foods.—Speaking generally, the methods employed to preserve food-stuffs are based upon one or more of the following plans:—(1) Drying, (2) smoking, (3) freezing or refrigerating, (4) sterilisation, (5) pasteurisation, (6) exclusion of air, (7) the addition of chemicals. The fundamental idea underlying all these procedures is either the exclusion, inhibition, or actual destruction of micro-organisms likely to cause the food to decompose.

Drying of food is a very old method of preserving it, and is essentially a procedure designed to inhibit microbic activity by the withdrawal of moisture. Familiar examples of this class are the biltong of the Kaffirs and Boers, the charqui of the South American, dried milk, dried vegetables, dried bread or "pain biscuité" and dried eggs.

The powerfully destructive effect of smoke on certain micro-organisms is well known, hence exposure of food to smoke from smouldering wood for purposes of preservation dates back to old times. The beneficial action of this smoke probably depends upon the twofold effect of drying and the absorption of certain antiseptics (creosote) from the fumes of the burning fuel. As in the case of drying, it is doubtful whether smoking affords any certainty of the destruction of germs other than those on the surface of the food, but within certain limitations we may accept it as efficient.

Freezing and refrigeration can be regarded only as temporary means of arresting microbic activity in a food, which recommences as soon as the article is placed in a temperature above 10° C. However, as a method of storing perishable foods, such as meat, fish, poultry and dairy products, it has revolutionised more than one branch of provisioning.

In sterilisation, using the term to mean the actual destruction of micro-organisms in and on food, we have the only safe means of preserving food-stuffs. It is secured by subjecting the articles for a short time to 100° C., or better still to 110° C., under pressure, and is employed chiefly for tinned foods, the enclosing tins being sealed hermetically during the process. The method is also applied largely to milk. In the case of sound meat or other food-stuff adequately sterilised, there are no disadvantages except

such as may arise possibly from the solution of the metal ; but it is exceedingly doubtful whether any food preserved in this way can take up sufficient metal to produce ill effects. When sickness has been recorded as due to a preserved food of this class, it was probably the result of some change which had taken place in the food-stuff with the production of ptomaines either before or after the canning process. It is notorious that in most cases where a canned food has produced symptoms of poisoning, it has presented some peculiarity in odour or taste, suggestive of retrograde changes.

The theory underlying pasteurisation has already been discussed ; as a practical method of food preservation, except for milk, cream, wines and beers, it occupies but a subordinate position.

When considering sterilisation of food by heat it was mentioned how often the process is associated with the enclosure of the food substance in a hermetically sealed covering or tin. This exclusion of air may be employed without such previous treatment, as, for instance, when we paint eggs over with a silicate, but owing to a failure to ensure sterilisation this method of simple air exclusion, no matter how performed, must be unsatisfactory. Instead of entirely excluding the air, meat has been preserved by removing some of the air and destroying the remainder of the oxygen by sodium sulphite ; this is M'Call's process. Another method (Jones and Trevithick's) consists of withdrawing the air, and substituting nitrogen and a little sulphur dioxide. These processes are not much used in the present day, as it is recognised that the essential need is previous destruction of bacteria ; this we know to be best secured by sterilisation by heat, and provided the subsequent exclusion of air be perfect, the food will keep for an indefinite period.

Tins of preserved meat, &c., are considered unfit to be received from contractors—(1) when perforated by nails ; (2) when there are any angular indentations which are likely to have caused partial fracture of the tin and render it liable to rust ; (3) when they contain deleterious gas, or are bulged or blown ; (4) when they are rusty ; (5) when it is found that the tin has not been hermetically sealed, so that the meat has either dried or putrefied in consequence. After being examined in relation to these points, the tins should be struck lightly with a small wooden mallet, and those producing a hollow sound, suggesting incipient putrefaction, or that the tins have not been filled to the full capacity, should be rejected.

When acid fruits are preserved in tin cases, tin is dissolved to such an extent as to communicate a distinct metallic taste to the food. Canned meat, soup, and vegetables are less liable to this contamination. Attfield, however, frequently detected minute particles of metallic tin by washing the external surface of meat just removed from a can. Hamel Roos found tin in all tinned foods, whether consisting of meat, fruit, or vegetables. Hehner also found tin in every variety of tinned food. In soups the tin was found distributed all through the food ; but in the case of hard meat it was found chiefly on the surface. In a recent case large numbers of tins of meat essence were found to contain as much as 2 grains of tin per pound of essence. The solvent action on tin in these cases is due to the presence of organic acids, such as lactic and carnic acid. This action can be prevented by coating the tin with a lacquer of shellac.*

While the foregoing methods of preserving food are open to little criticism, provided the food be sound and fresh when preserved, and the manipulations necessary for the act of preserving be carried out in a clean and wholesome way, it is otherwise with the increasingly prevalent practice of attempting to preserve food substances by means of chemical re-agents. The extent to

* See *Lancet*, February 24, 1906, p. 127 ; *also* January 5, 1907, p. 42.

which the use of preservatives and colouring-matters now prevails will be apparent from the following summary of the facts in regard to some common articles of diet. Cream and milk are constantly treated with boron compounds, formalin, carbonate of soda, salicylic acid or hydrogen peroxide; cheese and butter with boric acid, formalin, fluorin compounds and salicylic acid; margarine with annatto, boric acid and other re-agents used for butter; vegetables with sulphate of copper; meat, poultry and game with sulphurous acid to retain the red colour of meat and as a preservative; ginger beer, wines, cordials, juices and syrups with salicylic acid and sulphites; preserved fruits of all kinds with boric acid, salicylic acid and benzoic acid; jams with salicylic acid and fluorin compounds; beer with saccharin, salicylic acid and sulphites; potted meats with benzoic acid, sulphites, salicylic and boric acids; bread and pickles with alum; hams by treatment with "smokene" a preparation consisting of borax, salt, creosote and a coal-tar dye.*

The objections to all these methods are mainly two, first, they permit the placing upon the market of stale or damaged food-stuffs, and tend to conceal possible original defects in these articles which, without the presence of preservatives would be only too rapidly manifest; secondly, there is reason to believe that the continuous ingestion of considerable quantities of these chemical re-agents may not be without deleterious effects upon the consumer. On the other hand, we are bound to admit that the practical application of various antiseptics to the preservation of food has permitted the utilisation of many aliments which otherwise would have been wasted or at least been left beyond the reach of the greater number of people. Of the two objections to the routine use of preservatives in food the second one is the more serious, but when we come to look into the evidence in support of the allegation as to their prejudicial effects on health we find it anything but clear. The literature on the subject is extensive, and we can but discuss it in a most elementary manner. Experiment and clinical evidence indicate that both salt and saltpetre can induce irritation and inflammation of mucous membranes, but there is little evidence to show that the proportions used in curing flesh foods is sufficient to produce these effects. On the contrary, the universal and long-established custom of using them as a means of food preservation suggests that such is not the case. When we turn to examine the effects of boron compounds on the digestive processes and on the body generally, we find some diversity of opinion. Many experiments have been carried out both *in vitro* and *in vivo* to settle this point, notably by Liebreich,† Chittenden,‡ Rideal and Foulerton,§ Tunnicliffe and Rosenheim,|| Forster,¶ and Wiley.** The student should study this literature for himself, but from our own point of view we feel sure that boron compounds contained in articles of food undoubtedly give rise to no inconsiderable amount of indigestion by interfering with the normal action of the digestive ferments, especially in children; further, there is overwhelming evidence that to those suffering from kidney affections their ingestion is most harmful. As regards formaldehyde, experiments show that, comparing it with boron compounds, it exerts a

* Thresh and Porter, *op. cit.* p. 9.

† Liebreich: *Effects of Borax and Boric Acid on the Human System*, London, 1906.

‡ Chittenden: *Dietetic and Hygienic Gazette*, February 1893; also *New York Med. Journal*, February 26, 1898.

§ Rideal and Foulerton: *Lancet*, November 1899; see also *Public Health*, 1899.

|| Tunnicliffe and Rosenheim: *Journal of Hygiene*, vol. i. pp. 168 and 321.

¶ Forster: *Archiv. f. Hygiene*, 1884, ii. p. 109.

** Wiley: Circular No. 15, Bureau of Chemistry, United States Board of Agriculture.

more prejudicial effect on the digestive ferments and on the nutrition of children. We question whether some of the alleged relationship between skin affections and formalin in milk is based on sound facts; it is, however, suggestive of the need for careful attention to its possibility. The evidence concerning the effects of sulphites on the body are similar, especially in regard to the risk of insidious production of kidney disease. There appears to be little or no evidence that salicylic or benzoic acids, employed as food preservatives, produce injurious effects, but of the two probably the latter is likely to be the least harmful. The introduction of fluorin compounds as preservatives for butter, cream and beer is of comparative recent date, and few observations have been made concerning their effects on man, but sufficient is known of their toxic and disturbing effects to indicate the danger attaching to their ingestion with food. It must be confessed that the whole question of preservatives in food is one of some complexity, but those desirous of studying it in detail should consult the Report of the special Committee of the Local Government Board * to which we ourselves are much indebted for valuable information. That committee made the following recommendations:—(1) That the use of formaldehyde in food and drink be absolutely prohibited, and that salicylic acid be not used in greater proportion than 1 grain per pint or pound respectively for liquid or solid food, its presence in all cases to be declared; (2) that the use of any preservatives or colouring-matter in milk be made an offence under the Sale of Food and Drugs Acts; (3) that boric acid preservatives only be allowed in cream, the amount not to exceed 0·25 per cent. and be notified on a label; (4) that boric acid preservatives only be allowed in butter, the amount not to exceed 0·5 per cent.; (5) that chemical preservatives be prohibited in all dietetic preparations for the use of children and invalids; (6) that the use of copper salts for "greening" be prohibited; (7) that a Court of Reference be established to supervise the use of preservatives and colouring-matters in food.

These suggestions have remained as recommendations only, and are of no legal value, though a recent circular from the Local Government Board to Sanitary Authorities lays down certain principles for their guidance. These are, as regards formalin, "the presence in milk of formalin to an amount that is ascertained, by examination within three days of collecting the sample, to exceed 1 part in 40,000 (1 part of formic aldehyde in 100,000) raises a strong presumption that the article has been rendered injurious to health, and that the purchaser has been prejudiced in the above sense." A similar presumption is raised "where boron preservatives are present in milk to an amount exceeding 57 parts of boric acid per 100,000, or 40 grains of boric acid per gallon."

There can be no doubt that the whole question of the control of foods which are tinned or prepared for sale needs legislative attention, for there is evidence of the existence of much unclean and unwholesome preparation of foods of this kind. There is only one way of effective administrative control of such industries, and that is by a system of inspection at the time of manufacture, this inspection should be concerned with (*a*) the quality and condition of the original constituents of the prepared food; (*b*) the manner of its preparation; and (*c*) the premises where it is prepared. In other words, the general policy of protecting the sources of bread, water, butter and other articles should now be applied to meat, milk and shell-fish. All our experience of outbreaks of disease following the consumption of

* Report of the Departmental Committee on the Use of Preservatives in Food, 1901.

preserved or prepared articles of food lead to the conclusion that poisonous properties are contracted by putrefaction or unsoundness in the meat or gelatin, or unclean manipulation or storage in insanitary places. In addition to such channels of infection there is a possibility of failure to secure sterilisation in the cooking process.

THE LAW AS TO ADULTERATION OF FOOD.

The legislative enactments relating to this matter, in respect of the whole of Great Britain and Ireland, are contained in the Sale of Food and Drugs Act, 1875, the Sale of Food and Drugs Act Amendment Act, 1879, the Margarine Act, 1887 (so far as concerns England and Wales), the Local Government Act, 1888, and the Sale of Food and Drugs Act, 1899, which extends to the whole of the United Kingdom.

Section 26 of the Sale of Food and Drugs Act, 1899, defines "food" for the purposes of the Sale of Food and Drugs Act as including every article used for food or drink by man, other than drugs or water, and any article which ordinarily enters into or is used in the composition or preparation of human food; and shall also include flavouring matters and condiments. The Sale of Food and Drugs Act, 1875, further provides that "no person shall mix, colour, stain, or powder (or order or permit any other person to mix, colour, stain, or powder) any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state; and no person shall sell any article so mixed, coloured, stained, or powdered, under a penalty not exceeding £50 for a first offence, and, on a subsequent conviction, of imprisonment with hard labour for a period not exceeding six months" (section 3). The same prohibitions and penalties apply to the like treatment of drugs (section 4), but no liability is incurred if the accused person can show that he was unaware of the admixture, and could not "with reasonable diligence" have known that the food or drug was so adulterated (section 5).

Further, "no person shall sell, to the prejudice of the purchaser, any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser, under a penalty not exceeding £20; but no offence shall be deemed to be committed under this section in the following cases:—(1) Where any matter or ingredient not injurious to health has been added to the food or drug because the same is required for the production or preparation thereof as an article of commerce in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight, or measure of the food or drug, or conceal the inferior quality thereof; (2) where the drug or food is a proprietary medicine, or is the subject of a patent in force, and is supplied in the state required by the specification of the patent; (3) where the food or drug is compounded . . . [and the provisions of the seventh and eighth sections are observed]; (4) where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation" (section 6).

As regards these exemptions, the *onus probandi* rests with the defendant (section 24). No person shall sell any compound, drug, or article of food which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding £20 (section 7); but no offence under this section is committed in respect of the sale of a drug or article of food mixed with an ingredient not injurious to health if it is labelled as "mixed" at the time of the sale (section 8).

Section 9 of the Act provides that "no person shall (with the intent that the same may be sold in its altered state without notice) abstract from an article of food any part of it, so as to affect injuriously its quality, substance, or nature; and no person shall sell any article so altered without making disclosure of the alteration, under a penalty not exceeding £20." In any prosecution under this Act, the defendant is to be discharged if he proves to the satisfaction of the Court (*a*) that he brought the article as being the same in nature, substance, and quality with that demanded by the purchaser, and with a written warranty to that effect; (*b*) that at the time of sale he had no reason to believe it to be otherwise; and (*c*) that he sold it in the same state as when he purchased it (section 25).

In order to carry out the provisions of this Act, in every district a competent person may be, and if required by the Local Government Board must be, appointed as Public Analyst (section 10). Every Public Analyst appointed on or after January 1, 1900, will be required to furnish sufficient proof of his competent skill and knowledge of analytical chemistry, therapeutics, and microscopy. The Local Government Board accept as sufficient evidence of competency the Diploma of Fellowship or Membership of the Institute of Chemistry, together with the certificate granted by the Institute after examination. The diploma as a registered medical practitioner is accepted as sufficient proof of competency in microscopy and therapeutics, but evidence of a sufficient skill and knowledge of analytical chemistry will also have to be furnished. In the case of boroughs having a separate Court of Quarter Sessions, or a separate police force, this appointment is made by the Town Council; while for all other parts of the country the appointment is made by the County Council (Local Government Act, 1888, sections 3, 38, and 39). All these appointments and reappointments are subject to the approval of the Local Government Board. Where a Public Analyst is thus appointed, any purchaser of an article of food or drug within the district shall be entitled to have it analysed for a fee of 10*s.* 6*d.*, otherwise by another Public Analyst at such fee as he may require, and in either case to have a certificate of the result (section 12). The Medical Officer of Health, Inspector of Nuisances, or any officer charged by the Sanitary Authority with the execution of the Act, may procure samples of food and drugs, and submit them to the Public Analyst (section 13). The quantities of the samples purchased under section 13 should not be less than, in the case of milk, 1 pint; butter, $\frac{3}{4}$ of a lb.; lard, $\frac{3}{4}$ of a lb.; coffee, $\frac{3}{4}$ of a lb.; spirits, $\frac{3}{4}$ of a pint. Any person purchasing an article for analysis shall, upon the completion of the puchase, forthwith notify to the seller his intention to have it analysed by the *Public* Analyst, and shall offer to divide it into three parts, to be then and there separated, and each part to be marked and sealed or fastened up, and shall, if required to do so, proceed accordingly, and shall deliver one of the parts to the seller. One of the three parts must be retained for future comparison, and the third delivered up to the Public Analyst (section 14). If the seller does not accept the offer of division, the Analyst must divide the sample into two parts, sealing and delivering up one of them to the purchaser (section 15). Samples may be sent by registered parcel post to the Public Analyst, if his residence is two miles from that of the purchaser (section 16).

Any person refusing to sell to an officer of the Sanitary Authority any article of food or drug on sale by retail, the price being tendered, and the quantity demanded not being greater than is reasonably requisite, is liable to a penalty not exceeding £10 (section 17). The certificate of the Analyst must be in the following prescribed form (section 18):—

To [*name of person submitting the article*].

I, the undersigned, Public Analyst for the [*County, Borough, &c., of . . .*], do hereby certify that I received on the . . . day of . . . from [*name of person delivering it, or the postal officer*], a sample of [*description of article*] for analysis (which then weighed . . .) and have analysed the same, and declare the result of my analysis to be as follows—

I am of opinion that the same is a sample of genuine . . .

or

I am of opinion that the said sample contained the parts as under . . .

or

The percentages of foreign ingredients as under—

Observations.

As witness my hand, this . . . day of . . .

A. B.

At

When the article cannot conveniently be weighed, the passage in the certificate having reference thereto may be erased or the blank left unfilled. The above certificate of the Analyst is sufficient evidence of the facts therein stated, unless the defendant requires the Analyst to be called as a witness (section 21). The justices before whom a case is heard may, at the request of either party, cause any food or drug to be sent to the Commissioners of Inland Revenue for analysis by the chemists of their department at Somerset House (section 22).

Under the Sale of Food and Drugs Act, 1899, if there is imported into the United Kingdom margarine or margarine cheese, except in packages conspicuously marked margarine or margarine cheese; or adulterated or impoverished butter or milk or cream, except in packages or cans conspicuously marked with a name or description indicating that the butter or milk or cream has been so treated; or condensed, separated, or skimmed milk, except in tins or other receptacles which bear a label whereon the words "Machine-skimmed Milk" or "Skimmed Milk," as the case may require, are printed in large and legible type; or any adulterated or impoverished article of food to which His Majesty may, by Order in Council, direct that this section (1) shall be applied, unless the same be imported in packages or receptacles conspicuously marked with a name or description indicating that the article has been so treated; the importer shall be liable on summary conviction, for the first offence to a fine not exceeding £20, for the second offence to a fine not exceeding £50, and for any subsequent offence to a fine not exceeding £100.

Under section 4, Sale of Food and Drugs Act, 1899, the Board of Agriculture may, after such inquiry as they deem necessary, make regulations for determining what deficiency in any of the normal constituents of genuine milk, cream, butter, or cheese, or what addition of extraneous matter or proportion of water, in any sample of milk (including condensed milk), cream, butter, or cheese, shall, for the purposes of the Sale of Food and Drugs Act, raise a presumption, until the contrary is proved, that the milk, cream, butter, or cheese is not genuine, or is injurious to health, and an analyst shall have regard to such regulations in certifying the result of an analysis under these Acts. The regulations under this section shall be notified in the London and Edinburgh Gazettes. References have already been made to Regulations issued under this section; also when discussing the sanitary aspects of the milk and butter trade, mention has been made of the various Statutory Orders issued to control this important business.

CHAPTER VI

BEVERAGES AND CONDIMENTS

Almost as important to civilised man as the food-stuffs, which are absolutely necessary for existence, are substances which enable food to be taken with pleasure or relish; such substances have been appropriately called food accessories. The Germans call them "means of enjoyment," as distinguished from the true foods or "means of nourishment." They include substances varying from the simplest aromatic principles, such as one smells when meat is cooking, or condiments and spices, to the more complex alcoholic and non-alcoholic drinks which so largely enter into the daily dietaries of both civilised and uncivilised peoples. The general action of the food accessories seems to be to stimulate digestion, either directly by affecting the digestive organs, or indirectly through the central nervous system. The condiments are mainly added to food as flavouring agents; they include such articles as mustard, pepper, onions, cloves, nutmeg, cinnamon, salt, and vinegar. Excepting the two last, all these owe their value as food accessories to aromatic oils which they contain. These essential oils are all stimulants directly of the muscular movements of the digestive organs and of the secretion of their juices; but if taken in excess, easily induce gastric catarrh and exhaustion of the mucous lining of the stomach. The influence of common salt has already been discussed.

The food accessories taken in as beverages may be divided into three groups:—(1) The liquids containing alcohol, such as beer, wine, &c.; (2) the liquids containing the active principles caffein or theobromine, such as tea, coffee, Paraguay tea, cocoa, &c.; (3) the liquids containing large quantities of the organic acids and their salts, such as lime or lemon juice and vinegar. The alcoholic beverages owe their action as food accessories chiefly to the ethylic alcohol they contain; and the effect of the different alcoholic drinks is, broadly speaking, proportional to the amount of alcohol present in them, but not entirely so, since many of them owe part of their effect to the action of certain aromatic substances and other principles. For these reasons, therefore, the presence of these other principles must be considered as well as the alcohol in deciding the utility or otherwise of any given alcoholic drink.

For the sake of convenience, and also according to the amount of alcohol they contain, the alcoholic beverages may be divided into beers, light wines, sweet wines, and spirits.

BEER.

The usual definition of beer was, "a fermented infusion of malt flavoured with hops." This, however, is not quite correct, at the present day, as sugar largely takes the place of malt, and other vegetable bitters that of hops, so that probably a more accurate definition would be, to call it a fermented saccharine infusion to which has been added any wholesome

bitter. Formerly the substitution of quassia, gentian, calumba, or any other bitter in place of hops was illegal, but now it is not the case, with the result that all kinds of bitters may be used, provided they are wholesome. As a matter of fact, however, in the best beers even now, the only bitter used is hops.

Modern beers may be divided into two great groups, namely, the non-malt beers and the malt beers. What are called non-malt beers are those made by a yeast fermentation of an infusion of sugar, mainly derived from starch chemically or artificially converted, as by the action of sulphuric acid. Malt beers are the result of a similar yeast fermentation of an infusion of sugar, only in this case the sugar is derived from the natural conversion of grain starch by means of germination or malting. In both instances, the resulting liquor is an alcoholic one in which a portion of the alcohol becomes transformed into aldehyde and subsequently by a further oxidation changed into acetic acid.

The actual preparation of malt and the subsequent brewing of beer is practically as follows. The maltster first soaks his barley in a cistern for some fifty hours; he then transfers it to the "couch" and twenty-four hours later spreads it out on floors in a malting. Here he leaves it for ten or fourteen days, during which time germination takes place and the grain sprouts. After this sprouting has taken place sufficiently, all germination action is arrested by drying the grain over a kiln. It is now malt, and if tasted is distinctly sweet, owing to the conversion of the grain starch into sugar by the action of the diastase ferment. After the dried malt has been sifted or screened so as to break off all the sproutings, it passes into the hands of the brewer, who, after crushing it, places it in his mash-tub with water warmed to about 160° F. This water completes the transformation of the starch into grape-sugar and dissolves it, causing the resulting liquor, or *wort* as it is called, to have a decidedly sweet taste.

In the case of a brewer using chemically converted starch (saccharum) or a mixture of it with malt, a similar treatment with warm water would be followed by the production of a sweet liquor or wort. When the conversion of the starch into sugar is sufficiently complete, all chance of further conversion is stopped by boiling the wort, which also acts in coagulating the albumin which the water has dissolved out of the grain; advantage is also taken of the boiling to add hops, which aid further in clearing the wort by coagulating the remaining albuminous matters, besides imparting to it their characteristic bitterness. Both the length of the boiling and the quantity of hops added vary, according to the richness of the wort in sugar, and the quality of beer it is intended to make.

The next step in brewing is to run off the boiled liquid into shallow vessels, in which it is cooled to the best temperature for fermentation. If "top" yeast is to be used, this temperature is 60° F., but if what is called "bottom" or sedimentary yeast, as used in Bavaria, a much lower temperature is preferable. When at the required heat, the liquid is run into the fermenting tun and a sufficient quantity of yeast is added. It is usual to employ a yeast obtained from a kind of beer different from that which it is proposed to make; the whole is allowed to ferment slowly for six or eight days. During this time, the sugar splits up into alcohol which remains in the beer, and into carbonic acid gas which, for the most part, escapes into the air. The most essential points in brewing are that the quantity of yeast to be added and the temperature at which fermentation is allowed to take place, vary with different kinds of beer; also that yeast works better when transferred from one kind of beer to

another; and that the fermentation must be so regulated that the whole of the sugar contained in the wort is not transformed into alcohol, as if it is all so transformed the beer does not keep well; that is, it would turn sour in the casks. This turning sour is due mainly to the passage of the alcohol into aldehyde and the subsequent oxidation of this into acetic acid.

There are many varieties of ales and beers, the chief being :—*Pale* and *Mild Ales*, made from the finest dried malt and the best hops; the mild ale is usually sweeter, stronger, and less bitter than the pale. *Porter* is nothing more than a weak mild ale, coloured and flavoured with roasted malt. *Stout* is a richer and stronger kind of porter. The *German beers* are fermented by means of sedimentary yeast as distinguished from the surface yeast used in England. Their fermentation is carried on at a lower temperature than in the case of British beers. They contain also less alcohol than the English, but are richer in carbonic acid gas, and keep better. *Lager* and *Bock* beer is made from a stronger wort, and is proportionately richer in alcohol and malt extract. The *Belgian beers* are made with unmalted wheat and barley; they take long periods to ferment, doing so spontaneously, no yeast being added; as a rule, they are hard from the presence of much acid. *Bottled beers* are all bottled while fermentation is going on, and owe their sparkling and frothing to the excess of carbonic acid in them. German *White Beer* is an acidulous beverage chiefly obtained from barley and wheat malt by rapid top fermentation, the properties of which differ much at different places. It is mostly sold in bottles. When required in bottles in a briskly effervescing state and clear, an addition of an enlivening material is necessary in the form of cane-sugar. Only by this means can a productive secondary fermentation be kept up in the bottles, as the main fermentation almost entirely consumes the fermentable material. The *Vienna beers*, like the German lighter beers, are remarkable for producing neither intoxication nor drowsiness, due principally to the small quantity of alcohol they contain.

The German or Bavarian process of brewing differs in several important points from that practised in England, and we may refer to these points for an explanation of the qualities—especially in regard to flavour, alcoholic strength, and the quantity of malt and hop extractives which sharply distinguish German from English beers. Thus the peculiar qualities, especially the flavour, of German or Austrian beers are doubtless to be ascribed, in a large measure, first to the fermentation being very slow, and carefully restricted to a low temperature; secondly, the employment of sedimentary yeast tends to render the products of a simpler, and doubtless more wholesome, nature than those which are evolved when a more rapid fermentation is allowed to proceed, such as occurs when a comparatively high temperature and top-growing yeast are adopted. Again, the quantity of hops used in the brewing of German beers in much less than is employed in this country, while in Bohemia and Bavaria the hops are gathered earlier, so as to exclude much of the narcotic principles which longer growth fosters. Since, as is well known, the constituents of the hop are distinctly narcotic, this, in addition to the decreased percentage of spirit, would account for the comparative absence of drowsy symptoms when Bavarian, German, or Austrian beer is drunk, but which so frequently follow the consumption of English beers.

Composition of Beer.—The specific gravity varies from 1006 to 1030, or even more. The average in English ales and porters is from 1010 to 1014. The percentage of extract is from 4 to 15 per cent. in ale, and from 4 to 9 per cent. in porter. It is least in the bitter, and highest in the

sweet ales. The alcohol varies from 1 to 10 per cent. in volume. The free acidity which arises from lactic, acetic, gallic, and malic acids ranges (if reckoned as glacial acetic acid) from 18 to 45 grains per pint. The fermentation produces, besides alcohol and carbonic acid, a little glycerin and succinic acid. There is a small quantity of albuminous matter in most beers, not averaging more than 0·5 per cent. The salts average 0·1 to 0·2 per cent., and consist of alkaline chlorides and phosphates, and some earthy phosphates. There is a small amount of ammoniacal salt. The dark beers, or porters, contain caramel and assamar. Free carbon dioxide is always more or less present; the average is 0·1 to 0·2 part by weight per cent., or about $1\frac{3}{4}$ cubic inch per ounce. Volatile and essential oils are also present.

A more exact statement of the percentage composition of various beers is presented in the following table :—

	Alcohol by Vol.	Total Extract.	Protein.	Sugar.	Dextrins.	Acidity as Acetic Acid.	Ash.
English Ale	4·89	6·03	0·52	0·84	—	0·31	0·31
Allsopp's Lager	5·40	—	0·40	2·04	3·34	0·12	0·28
Burton Ale	4·62	4·4	0·46	1·10	2·06	0·29	0·35
Guinness's Stout	5·40	5·4	0·52	0·95	2·77	0·30	0·36
Spatenbrau	3·23	6·6	0·68	0·88	—	0·19	0·27
Pilsener	3·46	4·9	0·37	1·33	—	0·16	0·20
Munich Bockbier	4·07	7·2	0·71	0·90	—	0·17	0·26
Munich Hofbrau	3·70	5·8	0·55	1·20	—	0·21	0·24

Roughly speaking it may be said that a pint of good bottled beer contains 1 fluid ounce of alcohol, $1\frac{1}{2}$ ounces of sugary extract, 20 grains of free acid and 14 grains of salts.

The water used in brewing should, of course, be free from all injurious impurities, and especially from any organic matters undergoing change. It is well known that variations in the mineral constituents of the water used in brewing exert an important influence on the character of the finished beer. Hard and somewhat saline water, for instance, is preferred for the brewing of pale and bitter ales in this country, since it extracts less colouring-matter and, what is more important, less albuminous matter from the malt. It is the latter substances which, when present in excess, are fatal to the prime condition of English brewed ales. Thus, in England, hard waters are in general use for brewing. On the other hand, the German brewer uses a softer and practically non-saline water, which extracts a greater amount of albuminous principles. How much common salt is present is mainly interesting because in prosecutions for the addition of salt to beer, the defence frequently is, that the latter is a natural component of the beer from the water used in the brewing. As brewers, commonly, use hard waters, it is obvious that the waters in particular localities may contain varying quantities of salt. Generally speaking, the water used in different breweries gives quantities from 10 to 15 grains per gallon.

The malt extract is really the sum of the non-volatile constituents, and represents the residue of the extractive substances of the wort which have not been volatilised as carbonic acid during fermentation. In reality it consists of dextrin, sugar, cellulose, albuminous substances, and some fat from the malt or " saccharum " used, with lupulite and hop resin.

Formerly, the bitterness of beer was, by law, compelled to be derived solely from hops ; but since the repeal of the hop duty in 1862, any bitter may be used, provided it is harmless. From time to time various objectionable

bitters, such as picric acid, picrotoxin or colchicine, have been identified in beers, but only very rarely; in fact so rarely that they may be practically said to be now never used for the purpose. In the same way, quassiin, gentianin, absynthin, aloin, and some other more or less doubtful bitters have been found in beers, but extremely rarely. The chief bitter employed in beer to give it the characteristic flavour is that derived from hops. Hops are the cones or strobiles of the *Humulus Lupulus*. They contain about 4 per cent. of the astringent substance tannin, 1·5 per cent. of a fragrant essential oil, and much resin. These substances are chiefly found in the yellow glandular secretion of the hop cones, called *lupulin* or *lupulite*.

The ash of beer contains the mineral constituents that previously existed partly in the water, partly in the hops, and partly in the malt used. The ferric oxide, some phosphoric acid, a little lime and magnesia, with much of the silica remains undissolved and does not pass into the beer, the remainder is dissolved.

Nutritive Value of Beer.—In consequence of the abundant proportion of sugar and dextrin and the appreciable amount of albumin, beer has decidedly a nutritive value which is not insignificant. Even the alcohol, setting aside its toxic properties, must be viewed in a limited sense as a nutritive substance. Hitherto, no attempt has been made in this country to lay down any standards of composition for beer, with a view to control the nutritive value of this important means of popular enjoyment and nutrition. Beers or porters containing less than 3 per cent. of alcohol and 4 per cent. of extract must be pronounced weak, of inferior value, and not calculated to keep. While for ordinary ales, professing to be of fair or ordinary quality, the extract and alcohol may not unreasonably be expected to be each 4 per cent.; porters of the same class should yield at least 5 per cent. of extract and from 4 to 5 per cent. of alcohol. This is equivalent to expecting that the beer be brewed from an original wort having a specific gravity of from 1042 to 1054. Beers which, instead of being made from malt alone, receive additions of starch, maltose, potato sugar, &c., are relatively poorer in nitrogenous substances, ash and especially phosphoric acid. These non-malt beers retain their carbonic acid very imperfectly, hence readily get flat. Many of the German and Austrian beers, which contain small quantities of alcohol and large extracts are to be more regarded as food and drink than are the average British ales. In the former there is a lessened change by fermentation of the extract into alcohol and carbonic acid, whereby a greater nutritive residue in the form of malt extract is present, whereas in the British beers the reverse is generally the case. A pint of good ale contains as much carbo-hydrate as 1¼ ounces of bread, and an imperial pint of Allsopp will yield about 340 Calories of energy, or two pints will contain one-fifth of the total energy required daily; while five litres of good German beer should yield 250 grammes of carbo-hydrate in addition to 100 grammes of alcohol.

What is known as "small beer" is a thin beer often drawn for workmen and servants, containing only 1 to 2 per cent. of extract, about 1 per cent. of alcohol, and from 0·06 to 0·08 of ash. This beer is obtained by a repeated extraction of the malt which has been once used for ordinary beer, and then treating the resulting thin wort as for beer. The keeping properties of this liquid are very low; it readily becomes yeasty and sour, and has practically no nutritive value at all.

Adulterations of Beer.—The chief and simplest adulteration of beer is by the addition of water. Another very common adulteration is salt, the object of this addition being not so much to develop the flavour and

to preserve the liquor, as to produce a craving for more drink. The use of gypsum can hardly be regarded as an adulteration. Sulphuric acid is occasionally added to clarify beer, and to give it the hard flavour of age. In order to ensure its keeping, both sulphite of calcium and salicylic acid are used. The former falls down quickly as a sulphate and does no harm. Of the latter, about half an ounce is added to a 36 gallon cask; it cannot be said to do harm, but may affect the flavour of the beer to a slight extent.

Inasmuch as we are not able now to limit our conception of ideal beer to its being a beverage consisting purely of barley malt, water and hops, we are unable to consider the various substitutes for barley malt, such as wheat, rice, maize, potato starch, maltose, glucose, &c., as in any way adulterants. Our position is somewhat similar in regard to the various substitutes for hops; these are not adulterants unless hurtful bitters. Mention has been already made of the fact that, at times, wormwood, marsh-rosemary, bitter-clover, box-tree, holy thistle, centaury, gentian, quassia, and various other bitters of a more or less harmless nature may be added to beer, while occasionally others of a more objectionable character, such as colchicum, picrotoxin and aloin, have been used; still the employment of these is so exceptional, and the use of genuine hops so general, that the serious consideration of beer adulteration or sophistication by these means is unnecessary.

EXAMINATION OF BEER.

In its general characters, a good beer should be clear, transparent and possessed of a semi-vinous flavour. It should not taste too acid, and if bitter, the bitterness should not be persistent. The quality of an ale or stout is most conveniently estimated by a determination of the amounts of its acidity, its contained alcohol and its original gravity.

Determination of the Acidity.—This is a very important matter, as the increase of acidity is an early effect when beer is undergoing changes. For determining the acidity, we need an alkaline solution, such as was described for estimating the acidity of bread (page 310) and of which 1 c.c. is equal to 6 milligrammes of acetic acid. The amount of this solution required to neutralise exactly a given quantity of beer is determined and expressed as acid in grains per pint or as a percentage. This, representing the total acidity of the beer, rarely exceeds 26 grains per pint; more commonly it is about 16 grains per pint or 0·182 per cent.

Specific Gravity at 60° F.	Volumes per cent. of Alcohol.	Specific Gravity at 60° F.	Volumes per cent. of Alcohol.	Specific Gravity at 60° F.	Volumes per cent. of Alcohol.
1000·0	0·00	990·2	7·00	979·0	17·00
999·9	0·05	989·0	8·00	978·0	18·00
999·8	0·15	987·8	9·00	977·0	19·00
999·1	0·55	986·6	10·00	976·0	20·00
998·5	1·00	985·4	11·00	970·9	25·00
997·0	2·00	984·3	12·00	965·4	30·00
995·6	3·00	983·2	13·00	959·2	35·00
994·2	4·00	982·1	14·00	951·9	40·00
992·9	5·00	981·1	15·00	950·3	41·00
991·5	6·00	980·0	16·00	948·7	42·00

Determination of the Alcohol and Original Gravity.—For these estimations the following procedure is necessary. By means of a gravity bottle determine the specific gravity of the sample at 60° F.; next

evaporate 200 c.c. of the beer or stout down to about one-third, allow to cool, measure and re-make up to its original volume with distilled water, and then determine the specific gravity of this de-alcoholised beer at 60° F. Deduct the gravity obtained before evaporation from that after it, and take the difference from 1000. Having obtained this figure, refer to the table of degrees of specific gravities, given on page 344, and read off opposite the number obtained the percentage of alcohol present.

From the same data, practically, the gravity of the original wort from which the beer was brewed can be calculated. Taking the difference between the two gravities, obtained respectively before and after de-alcoholisation, we obtain a figure or number which is called the approximate spirit indication. Next determine the acidity of the beer as a percentage of acetic acid; from the following acidity table, read off the spirit indication corresponding to this acidity. Add this figure to that of the approximate spirit indication, and we get what is called the true spirit indication.

Table for ascertaining the Spirit Value of Active Acid in Beer.

Percentage of Acetic Acid.	Corresponding Degrees of Spirit Indication.									
	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
0·0	—	0·02	0·04	0·06	0·07	0·08	0·09	0·11	0·12	0·13
0·1	0·14	0·15	0·17	0·18	0·19	0·21	0·22	0·23	0·24	0·26
0·2	0·27	0·28	0·29	0·31	0·32	0·33	0·34	0·35	0·37	0·38
0·3	0·39	0·40	0·42	0·43	0·44	0·46	0·47	0·48	0·49	0·51
0·4	0·52	0·53	0·55	0·56	0·57	0·59	0·60	0·61	0·62	0·64
0·5	0·65	0·66	0·67	0·69	0·70	0·71	0·72	0·73	0·75	0·76
0·6	0·77	0·78	0·80	0·81	0·82	0·84	0·85	0·86	0·87	0·89

From the Table on page 346, read off the gravity (representing sugary extract which has fermented or become converted into alcohol and acid) corresponding to this spirit indication. If this figure be now added to the gravity given by the de-alcoholised beer (representing unfermented sugary extract) we get the probable original gravity of the wort from which the beer was brewed.

Example.—Say a beer sample has yielded 0·04 per cent. of acetic acid, and that the first and second gravities were respectively 1016·47 and 1023·36; the difference between these gravities is 6·89, and this taken from 1000 gives 993·11, corresponding in the alcohol table to 4·84 per cent. of contained alcohol. The original gravity of the wort would be calculated as follows:—The difference between the two gravities taken before and after de-alcoholisation we know to be 6·89, while the percentage of acetic acid is 0·04, corresponding by the acidity table to a spirit indication of 0·07. Then 6.89 *plus* 0·07 gives a true spirit indication of 6·96, which, by a reference to the other table, is equivalent to 28·6 degrees of gravity lost by fermentation. Then, as the second gravity, or that obtained after de-alcoholisation and representing unfermented extract, is 1023·36; by adding this to 28·6 we get 1051·96 as the probable original gravity of the wort from which the actual beer sample was brewed.

Some idea as to the solids or extract per cent. in a beer or stout can be obtained if, after taking the specific gravity after de-alcoholisation, the excess of gravity over 1000 be divided by 4; this gives an approximate conclusion as to the body of the beer; the more extract, the greater the nutritive value of the sample. In the example given above, the extract would be calculated as being one-fourth of 23·36 or 5·84 per cent.

TABLE SHOWING DEGREES OF SPIRIT INDICATION, WITH CORRESPONDING DEGREES OF GRAVITY LOST.

Spirit Indication.	Hundredths of a Degree.									
Degrees and Tenths.	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
4·0	15·10	15·14	15·18	15·22	15·26	15·30	15·34	15·38	15·42	15·46
·1	15·50	15·55	15·60	15·65	15·70	15·75	15·80	15·85	15·90	15·95
·2	16·00	16·04	16·08	16·12	16·16	16·20	16·24	16·28	16·32	16·36
·3	16·40	16·44	16·48	16·52	16·56	16·60	16·64	16·68	16·72	16·76
·4	16·80	16·85	16·90	16·95	17·00	17·05	17·10	17·15	17·20	17·25
·5	17·30	17·34	17·38	17·42	17·46	17·50	17·54	17·58	17·62	17·66
·6	17·70	17·75	17·80	17·85	17·90	17·95	18·00	18·05	18·10	18·15
·7	18·20	18·24	18·28	18·32	18·36	18·40	18·44	18·48	18·52	18·56
·8	18·60	18·65	18·70	18·75	18·80	18·85	18·90	18·95	19·00	19·05
·9	19·10	19·14	19·18	19·22	19·26	19·30	19·34	19·38	19·42	19·46
5·0	19·50	19·54	19·58	19·62	19·66	19·70	19·74	19·78	19·82	19·86
·1	19·90	19·95	20·00	20·05	20·10	20·15	20·20	20·25	20·30	20·35
·2	20·40	20·45	20·50	20·55	20·60	20·65	20·70	20·75	20·80	20·85
·3	20·90	20·94	20·98	21·02	21·06	21·10	21·14	21·18	21·22	21·26
·4	21·30	21·35	21·40	21·45	21·50	21·55	21·60	21·65	21·70	21·75
·5	21·80	21·84	21·88	21·92	21·96	22·00	22·04	22·08	22·12	22·16
·6	22·20	22·25	22·30	22·35	22·40	22·45	22·50	22·55	22·60	22·65
·7	22·70	22·74	22·78	22·82	22·86	22·90	22·94	22·98	23·02	23·06
·8	23·10	23·15	23·20	23·25	23·30	23·35	23·40	23·45	23·50	23·55
·9	23·60	23·65	23·70	23·75	23·80	23·85	23·90	23·95	24·00	24·05
6·0	24·10	24·15	24·20	24·25	24·30	24·35	24·40	24·45	24·50	24·55
·1	24·60	24·65	24·68	24·72	24·76	24·80	24·84	24·88	24·92	24·96
·2	25·00	25·05	25·10	25·15	25·20	25·25	25·30	25·35	25·40	25·45
·3	25·50	25·55	25·60	25·65	25·70	25·75	25·80	25·85	25·90	25·95
·4	26·00	26·04	26·08	26·12	26·16	26·20	26·24	26·28	26·32	26·36
·5	26·40	26·45	26·50	26·55	26·60	26·65	26·70	26·75	26·80	26·85
·6	26·90	26·95	27·00	27·05	27·10	27·15	27·20	27·25	27·30	27·35
·7	27·40	27·44	27·48	27·52	27·56	27·60	27·64	27·68	27·72	27·76
·8	27·80	27·85	27·90	27·95	28·00	28·05	28·10	28·15	28·20	28·25
·9	28·30	28·35	28·40	28·45	28·50	28·55	28·60	28·65	28·70	28·75
7·0	28·80	28·84	28·88	28·92	28·96	29·00	29·04	29·08	29·12	29·16
·1	29·20	29·25	29·30	29·35	29·40	29·45	29·50	29·55	29·60	29·65
·2	29·70	29·75	29·80	29·85	29·90	29·95	30·00	30·05	30·10	30·15
·3	30·20	30·25	30·30	30·35	30·40	30·45	30·50	30·55	30·60	30·65
·4	30·70	30·75	30·80	30·85	30·90	30·95	31·00	31·05	31·10	31·15
·5	31·20	31·25	31·30	31·35	31·40	31·45	31·50	31·55	31·60	31·65
·6	31·70	31·75	31·80	31·85	31·90	31·95	32·00	32·05	32·10	32·15
·7	32·20	32·25	32·30	32·35	32·40	32·45	32·50	32·55	32·60	32·65
·8	32·70	32·75	32·80	32·85	32·90	32·95	33·00	33·05	33·10	33·15
·9	33·20	33·25	33·30	33·35	33·40	33·45	33·50	33·55	33·60	33·65
8·0	33·70	33·76	33·82	33·88	33·94	34·00	34·06	34·12	34·18	34·24
·1	34·30	34·35	34·40	34·45	34·50	34·55	34·60	34·65	34·70	34·75
·2	34·80	34·86	34·92	34·98	35·05	35·10	35·16	35·22	35·28	35·34
·3	35·40	35·45	35·50	35·55	35·60	35·65	35·70	35·75	35·80	35·85
·4	35·90	35·96	36·02	36·08	36·14	36·20	36·26	36·32	36·38	36·44
·5	36·50	36·55	36·60	36·65	36·70	36·75	36·80	36·85	36·90	36·95
·6	37·00	37·05	37·10	37·15	37·20	37·25	37·30	37·35	37·40	37·45
·7	37·50	37·55	37·60	37·65	37·70	37·75	37·80	37·85	37·90	37·95
·8	38·00	38·06	38·12	38·18	38·24	38·30	38·36	38·42	38·48	38·54
·9	38·60	38·65	38·70	38·75	38·80	38·85	38·90	38·95	39·00	39·05
9·0	39·10	39·16	39·22	39·28	39·34	39·40	39·46	39·52	39·58	39·64
·1	39·70	39·75	39·80	39·85	39·90	39·95	40·00	40·05	40·10	40·15
·2	40·20	40·25	40·30	40·35	40·40	40·45	40·50	40·55	40·60	40·65
·3	40·70	40·75	40·80	40·85	40·90	40·95	41·00	41·05	41·10	41·15
·4	41·20	41·25	41·30	41·35	41·40	41·45	41·50	41·55	41·60	41·65
·5	41·70	41·75	41·80	41·85	41·90	41·95	42·00	42·05	42·10	42·15
·6	42·20	42·25	42·30	42·35	42·40	42·45	42·50	42·55	42·60	42·65
·7	42·70	42·75	42·80	42·85	42·90	42·95	43·00	43·05	43·10	43·15
·8	43·20	43·25	43·30	43·35	43·40	43·45	43·50	43·55	43·60	43·65
·9	43·70	43·75	43·80	43·85	43·90	43·95	44·00	44·05	44·10	44·15

WINE.

The term "wine" is held to mean "the fermented juice of the grape with such additions only as are essential to the stability or keeping quality of the wine." This definition admits as wines those beverages which, made from grape juice, require the addition of spirit to preserve them, as is the case with some wines from Spain and Portugal; but it excludes the so-called British wines, which are not made from the juice of the grape, and those wines from other countries which are fortified with spirit when they require no such addition.

When the sugary juice of a fruit, such as the grape, is left at a moderate temperature, fermentation takes place from the influence and action of germs which adhere to the skin of the grapes and are introduced into the "must" on pressing; this process differs very much from that in the making of beer, when the starchy or sugary infusion or wort is boiled, and then yeast added to make it ferment. During the fermentation of the fruit juice, a part or whole of the sugar is converted into alcohol. Various ethers, which give the characteristic flavour or bouquet to wine, are formed, as well as acetic, malic, succinic, and other acids. The essential acid of wine is tartaric acid; much of this crystallises in the casks as cream of tartar or tartrate of potash. The newer wines contain aldehyde, which is very intoxicating; later on this becomes oxidised into acetic acid, and, if exposed to the air long enough, all the alcohol in a wine will be converted into this acid so as to become practically ordinary wine vinegar. Much of the colour, taste, and character of wines depend upon how far they are made from the grape juice only, or how much this is mixed with the seeds and skins of the fruit. The seeds are rich in tannin and a bitter principle, while the skins yield a colouring-matter, some flavouring principle, and tannin. If it is desired to produce white wine, the "must" is quickly pressed away from the skins and stalks; while for red wine the skins of purple grapes are allowed to ferment along with the must, yielding thus a wine rich in tannin and colouring-matter.

	Specific Gravity.	Alcohol.	Extract.	Tartaric Acid.	Glycerin.	Mineral Salts.	Sugar.	Tannin and Colouring-matter.	Nitrogen.	Potash.	Phosphoric Acid.	Sulphuric Acid.
Red wine (French)	0·9982	7·80	2·56	0·57	0·730	0·248	—	0·180	0·043	0·106	0·030	0·033
" (Rhine)	0·9966	10·08	3·04	0·52	—	0·249	—	0·158	—	—	—	—
" (Austrian)	0·9958	8·49	2·54	0·62	0·810	0·241	—	0·110	0·026	0·101	0·037	0·033
" (Hungarian)	0·9952	9·02	2·54	0·67	0·790	0·215	—	0·150	0·034	0·091	0·038	0·024
" (Spanish)	0·9975	12·31	3·53	0·49	1·090	0·610	—	0·220	—	0·242	0·027	0·221
" (Australian)	0·9982	14·10	2·96	0·58	—	0·461	—	0·233	—	0·195	0·019	0·220
" ([illegible])	0·9976	11·36	2·86	0·62	—	0·550	—	0·226	0·021	0·231	0·230	0·225
White wine (French)	0·9963	10·31	3·03	0·66	0·970	0·250	—	—	—	0·098	0·032	0·038
" (Rhine)	1·0005	8·00	2·60	0·81	0·850	0·248	—	—	0·048	0·085	0·046	0·020
" (Austrian)	0·9949	7·93	2·13	0·67	0·680	0·189	—	—	0·022	0·081	0·034	0·039
" (Hungarian)	0·9955	8·00	2·33	0·69	0·770	0·204	—	—	0·027	0·075	0·036	0·026
Moselle	0·9964	7·99	2·24	0·79	0·720	0·175	—	—	0·031	0·068	0·034	0·025
Champagnes (Cliquot)	1·0565	10·20	19·75	0·60	1·130	0·120	17·520	—	—	—	0·016	0·022
" ([illegible])	1·0572	9·50	20·24	0·70	0·970	0·120	18·500	—	—	—	0·012	0·017
" ([illegible])	1·0280	8·21	10·15	0·57	0·230	0·135	8·450	—	—	0·059	0·016	0·025
Tokay	0·9943	12·05	3·26	0·68		0·240	1·040	0·630	0·041	0·108	0·035	0·030
Port	1·0081	16·69	8·05	0·40	0·430	0·233	5·843	0·430	0·027	0·102	0·031	0·023
Sherry	0·9932	17·45	3·98	0·45	0·520	0·380	2·120	—	—	0·206	0·031	0·128
Madeira	1·0003	15·40	5·52	0·43	0·740	0·350	3·230	—	0·020	0·149	0·060	0·075
Marsala	1·0022	15·85	5·27	0·49	0·510	0·380	3·530	—	—	0·142	0·029	0·114
Malaga	1·0694	11·93	21·73	0·55		0·410	17·110	—	0·041	0·187	0·049	0·043

Composition of Wines.—According to the absence or presence of sugar in them, wines are conveniently divided into two great classes, namely, the light red and white wines, from which sugar is either entirely absent or present in only very small amounts, and the sweet wines, such as Port, Sherry, and the Champagnes, in which sugar largely is present. The light wines and the sparkling wines differ slightly in the amount of contained alcohol, but chiefly differ in the quantity of ethers and aromatic substances. The champagnes differ largely from the ports and sherries in their effects, but as they contain frequently large amounts of sugar, they are best classed with them under the same heading of sweet wines. The composition of wines, it will be readily understood, is somewhat complex, and, moreover, very variable. So far as it is possible to summarise this information, the chief constituents and their percentage proportions are given in the preceding table, compiled mainly from large numbers of analyses made by Nessler and Borgmann.

Alcohol.—With regard to the amount of alcohol which a wine contains there is no constancy. All wines can be divided according to their alcoholic strength into two classes: the natural wines, containing from 6 to 13 per cent. by weight of alcohol; and the fortified wines, containing from 12 to 22 per cent. by weight of alcohol. The limit of alcoholic distinction between these two great classes of wine will be more readily understood if it be borne in mind that during the fermentation of any sugary liquid or mass, that process usually ceases when the alcohol formed reaches 14 per cent., so that any excess of alcohol over that amount must, of necessity, have been added artificially. The ports and sherries are all largely fortified with added alcohol; while many of the inferior clarets and champagnes are subject to very similar additions. The strongly alcoholic and fortified wines are slow to undergo change, hence keep well; but the lighter and natural wines deteriorate rapidly when exposed to air.

Ethers.—The chief of these present in wine are œnanthic, citric, malic, tartaric, acetic, racemic, butyric, caproic, caprylic, and some other ethers of indefinite composition. The "bouquet" of wine is partly owing to the volatile ethers and partly to extractive matter. The characteristic odour of wine is mainly due to œnanthic ether.

Albuminous Matters. Extractive Colouring-matter.—The quantity of albumin is not great; the extractives and colouring-matter vary in amount. The colouring-matter is derived from the grape skins; it is naturally greenish or blue, and is made violet and then red by the free acids of wine. The bluish tint of some Burgundy wines is owing, according to Mulder, to the very small amount of acetic acid which these wines contain. With age, changes occur in the extractive matters; some of it falls (apothema), especially in combination with tannic acid, and the wine becomes pale and less astringent.

Sugar exists in varying amounts, and in the form, for the most part, of fruit sugar. Sherry generally contains sugar, but not always; it averages 8 grains per ounce, and appears to be highest in the brown sherries, and least in Amontillado and Manzanilla. In Madeira it varies from 6 to 66 grains per ounce; in Marsala a little less; in Port, from 12 to 28 grains per ounce, being apparently nearer the latter in the finest wines. In Champagne it amounts to from 6 to 28 grains, the average being about 24 grains; but much Champagne is now drunk as "vin brut," without any sugar. In the Clarets, Burgundy, Rhine, and Moselle wines it is absent, or present in small amount.

Fat.—A small amount exists in some wine.

Free Acids.—Wine is acid from free acids and from acid salts, as the potassium bitartrate. The amount varies from 2 to 3 grains per ounce. The principal acids are racemic, tartaric, acetic, malic, tannic (in small quantities), glucic, succinic, lactic (?), carbonic, and fatty acids such as formic, butyric, or propionic. Some acids besides acetic are volatile, but it does not seem quite certain what they are. The tannic acid is derived from the skins; it is in greatest amount in new port wines; it is trifling in Madeira and the Rhine wines; it is present in all white and most red-fruit wines, except champagne. The tannic acid on keeping precipitates with some extractive and colouring-matter (apothema of tannic acid).

Salts.—The salts consist of bitartrate of potassium, tartrate of calcium and sodium, sulphate of potassium, a little phosphate of calcium and magnesium, chloride of sodium, and iron. The magnesia is in larger amount than the lime, and exists sometimes as malate and acetate. A little manganese and copper have been sometimes found. In Rhine wine a little ammonia is found (Mulder). The total amount of salts is 0·1 to 0·3 per cent., *i.e.*, about 9 to 26 grains per pint, or ½ to 1½ grain per ounce. The salts can only be detected by evaporation and ignition.

The total solids in wine vary from 3 to 14 per cent., or more in some of the rich liqueur-like wines. The specific gravity depends upon the amount of alcohol and of solids, and varies from 0·973 to 1·002 or more.

Artificial Improvement of Wine.—There are several processes which are frequently employed for either artificially improving wine, or increasing the volume. Thus, the addition of alcohol to the wine renders it stronger and more permanent; so, too, the addition of glycerin makes it sweeter and fuller in the mouth, and various essences render it more fragrant and highly flavoured. Various colouring-matters and preservative agents are also frequently added to wine, to improve the appearance and keeping qualities. Of the processes which aim exclusively at an increase of volume, the chief is the addition of alcohol and water, sometimes of glycerin. What is called "gallising" is the dilution of the "must," when it is too acid, by means of water until its acidity becomes normal (say 0·5 per cent.), and then adding cane- or grape-sugar until it contains from 20 to 30 per cent. Yeast wines are obtained by causing sugar-water to ferment with wine-yeast, with an addition of tartaric acid. Latterly much wine has been obtained by fermenting water and raisins, with the occasional addition of suitable ingredients. A manufacture of artificial wine from water, sugar, tartaric acid, and alcohol is by no means unknown.

Apart from adulterations in the direction of added spirit and artificial colouring, the most common sophistication of wine is "plastering" to secure clearness and dryness. The term "dryness," as applied to wines, means to express a flavour which is not that of sweetness. It has already been stated that the fermentation of grape juice, in the formation of wine, is the result of a vegetable growth, which the "must" or juice of the grape obtains spontaneously. Two distinct effects follow the growth of this fungus or process of fermentation; one is, the sugar of the "must" is converted into alcohol; the other is that the greater part of the albuminous or nitrogenous part of the "must" is consumed as food by the fungus. If left alone, the fermentation goes on until either all the sugar is used up, or until the supply of albuminous matter is exhausted. Now, it will be readily understood that the relative proportions of these present determine which of the two becomes exhausted first; and if the sugar is used up before the albuminous food of the fungus, a dry or not sweet wine is produced, while if the nitrogenous food is exhausted first, the remaining unfermented sugar produces

a sweet wine. Since the juice of the ripe grape contains from 10 to 30 per cent. of sugar, there is a very wide range.

A large number of people dislike sweet wines, hence the demand for what is called a dry wine. From what has been stated as to the difference in origin of a naturally sweet wine and a naturally dry wine, it will be apparent that the poorer the grape the drier the wine made from it; but the yield from a poor grape is less than that from a rich one, hence naturally dry wine costs more to produce than naturally sweet wine. It will also be apparent that the conversion of naturally sweet wines into dry ones will not be difficult, and since there is a demand for dry wines the artificial conversion is frequently performed. It is carried out either by making the wine from unripe or poor grapes, in which case the yield of alcohol and flavour are both low; or it is done by adding some nitrogenous material, such as gelatin, isinglass, or white of egg to the "must," so as to feed the yeast fungus until all or nearly all the sugar in the grape has been converted into alcohol. This procedure is sometimes called *fining* in the wine trade, and is the least objectionable of all methods of artificial drying, being, as it is, almost identical with the natural cause of wine dryness. Unfortunately, there are other methods adopted which are less commendable but more common. These consist often in making an imitation of the natural dryness of wine by adding fictitious salts and fortifying with alcohol. The sugar still exists as largely as before, only its taste is disguised.

Perhaps the most general method of increasing the dryness of a given wine is that of adding mineral acids and mineral salts, more particularly gypsum, or Spanish earth. This is technically known as "plastering," because gypsum is plaster of Paris. Gypsum, being largely sulphate of lime, modifies the chemical characters of the wine by decomposing the cream of tartar or potassium tartrate into calcium tartrate, potassium sulphate and free tartaric acid, at the same time altering the colouring-matter and changing the neutral organic compounds which exist in grape juice. The use of gypsum materially clears a wine, making it look brilliant; this is explained by the fact that the resulting sulphate of potash is much more soluble than the antecedent tartrate of potash. To a certain extent, after the addition of gypsum, much of the tartaric acid of wine is replaced by sulphuric acid, a body which renders wine, so altered, distinctly unsuitable for daily use. The sherries suffer the most from plastering—so much so, that some chemists advise that the plastering of wines should be called adulteration.

The chemistry of plastering may thus be written :—

$$\overset{\text{Gypsum.}}{CaSO_4} + \overset{\substack{\text{Potassium}\\ \text{bitartrate.}}}{C_4H_5KO_6} = \overset{\substack{\text{Acid potassium}\\ \text{sulphate.}}}{SO_4HK} + \overset{\substack{\text{Calcium}\\ \text{tartrate.}}}{C_4H_4CaO_6}.$$

A further transposition may ensue, such as the following, though, according to Roos and Thomas, it is questionable :—

$$\overset{\substack{\text{Acid potassium}\\ \text{sulphate.}}}{SO_4HK} + \overset{\substack{\text{Acid potassium}\\ \text{phosphate.}}}{PO_4H_2K} = \overset{\substack{\text{Neutral potassium}\\ \text{sulphate.}}}{SO_4K_2} + \overset{\text{Phosphoric acid.}}{PO_4H_3}.$$

The Nutritive Value of wines is small, and in the main subsidiary to the stimulating properties of the contained alcohol. Clarets and lighter wines are more or less anti-scorbutic, owing to the presence of the organic acids. Port and sherry appear to predispose to gout. The presence of some albuminous principles in wine may give it a slight nourishing value, but in favour of such a view the evidence is small. Like malt liquors, wines act as stimulants to the secretion of gastric juice, but they all have

a well-marked retarding effect on the chemical process of gastric digestion. According to Roberts, this retarding effect of both malt liquors and wines is not proportional to the amount of alcohol contained in them; there is something else which is more retarding than alcohol. Of the wines, port and sherry delay gastric digestion the most. Hock and claret have a less retarding effect, and champagne even still less. The retarding effects on digestion of wines and malt liquors is probably due to the neutral inorganic salts present, but the question cannot be yet regarded as settled.

EXAMINATION OF WINE.

This will be directed to ascertain Quality.

The Quality of wine can be best determined by noting the colour, transparency, and taste, and then determining the following points :—

Specific Gravity.—In the best clarets, before the loss of alcohol, the specific gravity is very nearly that of water. In some claret examined by Hoffmann, the specific gravity was 0·99952 and in others as low as 0·995. A low specific gravity shows that alcohol has been added, or that the solids are in small amount.

Amount of Alcohol.—A very small amount may show the addition of water, a large amount the addition of spirits. Its determination should be made as for beer.

Amount of Extract.—This may be estimated directly by evaporation of 50 c.c. on the water-bath in a weighed capsule and calculating the residue as a percentage. Indirectly, the extract of wine may be ascertained from the specific gravity of the de-alcoholised liquid as explained in the examination of beer, but the result is only approximate.

Amount of Free Acidity.—This is an important point, as it seems clear that some persons do not readily digest a large amount of acid and acid salts. The amount is determined by the alkaline solution as used for ascertaining the acidities of bread and beer. The total or free acidity is generally reckoned as crystallised tartaric acid ($C_4H_6O_6$), 1 c.c. of the standard alkaline solution being equal to 7·5 milligrammes. There is both fixed and volatile acidity; the relative amount of the two is difficult to determine satisfactorily, as some acid may be formed on distillation. The distillation should be conducted at a low temperature, so as not to decompose the fixed compound ethers. The volatile acidity is reckoned as glacial acetic, the fixed as tartaric acid. The volatile acids (acetic) in wine should not be present in a higher ratio than 1 to 3 of fixed acids (tartaric). If the proportion is higher than this, the wine is slightly turned, that is, on its way to become vinegar. Red wines contain usually more volatile acid than white.

The amount of free acidity varies greatly even in the same kind of wines; the least acid wines are Sherry, Port, Champagne, the best Claret and Madeira; the more acid wines are Burgundy, Rhine wine, Moselle. The amount of free acid in good Clarets is equal to 2 to 4 grains of tartaric acid per ounce; in common Clarets and in Beaujolais it may be 4 to 6 grains, and in some extremely acid wines it may be even more than this. In the best Champagnes it is 2 to 3 grains usually; but it has been known to reach in excellent Champagne 1·12 per cent., or 4·9 grains per ounce. In Port it averages 2 to 2½ grains, but may reach 4 grains; in Sherry, 1½ to 2½ grains; in the Rhine wines, 3½ to 4 or 6 grains. Thudichum and Dupré state that in good sound wine the amount of free acidity ranges from 0·3 to 0·7 per cent., or from 1·3 to 3 grains per ounce.

Excessive acidity of wine can be corrected by adding neutral potassium tartrate. Milk is also often used. The addition of the carbonated alkalies, or of chalk, alters the bouquet of the wine. When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea; about 1 ounce of tea boiled in 2 quarts of water should be added to about 40 gallons of wine. Bitter wine is treated with hard water or sulphur; bad smelling wine with charcoal; too astringent wine with gelatin; wine which tastes of the cask with olive oil.

Amount of Sugar.—This can be estimated by means of the copper solution used in the determination of lactose. It is, however, necessary to render the wine alkaline by an addition of sodium carbonate and to decolorise before using the Fehling solution. Strongly coloured wines, if their proportion of sugar is low, may be decolorised with purified animal charcoal; but if the sugar exceeds 0·5 per cent., with basic lead acetate, and should then receive more sodium carbonate. As animal charcoal retains sugar from strong sugary solutions, its use is inadmissible for wines containing much sugar. If there is reason to suspect cane-sugar, the sugar must be inverted by boiling with hydrochloric acid, the sugar re-determined with copper and the cane-sugar calculated from the difference. As an alternative to the use of Fehling's solution, the saccharometer may be employed, after decolorisation of the wine.

In using the copper solution for determining the sugar, if any substance exists which is still turned green by the alkali of the Fehling solution, the wine must be neutralised, evaporated to dryness, and the sugar dissolved. As a rule, the estimation of wine-sugar by means of the copper solution gives 0·5 per cent. too much sugar, and a correction to this amount should be made.

Other than added spirit, practically no preservation or adulterants are found in wines.

SPIRITS.

Of all the alcoholic beverages, spirits contain the largest amount of alcohol. They are all made by the distillation of alcohol from the fermentation of various saccharine or starchy materials. The more common spirits in this country are brandy, whisky, rum, and gin. The basis of all is ethylic alcohol, mixed with water; but they all contain other alcohols, usually classed together under the name of fusel oil, various compound ethers and fragrant bodies produced during distillation. It is the varying proportions of these latter which give the respective spirits their characteristic taste and aroma. After being kept for some years, spirits become mellowed or softened down; this was formerly supposed to be due to the diminution of the so-called fusel oil, but it is now more generally regarded as due to a lessening both in quantity and quality of the empyreumatic or flavouring substances.

The Table on page 353, taken from the Report of the *Lancet* Special Analytical Commission on Brandy, gives the chief points of importance.

Brandy is made by the distillation of fermented grape juice. When first distilled it is colourless, but gradually darkens with age, though too often artificially coloured by means of burnt sugar. Pure brandy consists of water, alcohol, acetic acid, acetic and œnanthic ethers, volatile oil, colouring-matter, and tannin. It usually contains from 45 to 55 per cent. of alcohol. The best kinds come from France, the more inferior from Spain, Portugal, and Italy. The chief adulterations are water, cayenne

pepper, burnt sugar, and acetic ether. Some of the cheaper brandies are not made from grape juice, but are mere imitations, made from corn spirit, flavoured and coloured. According to Wynter-Blyth, a very usual process of making brandy artificially in England is to add to every 100 parts of proof spirit from ½ to 1 lb. of argol, some bruised French plums, and a quart of good Cognac; the mixture is then distilled, and a little acetic ether, tannin, and burnt sugar added afterwards.

	Brandy.	Rum.	Gin.	Malt Whisky.	Grain Spirit.	Beet Spirit.
Alcohol per litre by weight.	410·50	619·20	401·50	436·20	932·60	912·90
" " volume	485·00	695·00	475·00	512·00	956·00	942·00
Equal to proof spirit per cent.	84·96	121·79	83·26	89·77	167·55	165·09
Extract per litre	6·70	6·36	0·52	1·16	*nil*	*nil*
Acidity as acetic acid	37·50	122·40	19·20	33·60	2·40	4·80
Ethylic aldehydes	6·10	15·41	4·72	14·38	1·15	10·92
Furfurol	0·82	2·08	0·13	1·94	*nil*	*nil*
Ethers, as ethyl acetate	53·35	308·00	8·80	38·72	3·52	17·60
Alcohol in ethers (not in total)	27·88	161·00	4·60	20·24	1·84	9·20
Higher alcohols	58·48	62·58	13·25	122·76	2·80	6·95

Whisky is really one of the corn spirits, being made from malted grain. The more inferior kinds are prepared from oats, barley, or rye, or from potatoes mashed up with malted barley and then roughly distilled and burnt in order to give it the peculiar smoky flavour characteristic of some varieties. Whisky usually contains from 40 to 50 per cent. of alcohol. Its adulterations are much the same as those of brandy.

As to what constitutes a true or genuine whisky has been the subject of important litigation, and it is a matter for regret that our food laws do not ensure, so far as possible, that the purchaser of a whisky shall obtain nothing differing from that which he wishes to buy. Much of the laxity which prevails arises from inadequate conceptions as to what constitutes "whisky," "blended whisky" and "compounded whisky." In ordinary speech it is usual to regard "compound" and "blend" as synonymous terms, but, strictly speaking, a distinction should be made between them, based upon the character of the ingredients entering into the mixture, so that while a compound is a combination of simples, a blend is a combination of like substances. In this sense, we can speak of a blend of coffees, a compound of coffee and chicory, but not a blend of coffee and chicory, or a compound of coffees. Applying these terms to the question of whisky, we can define that spirit as "a distillate from the fermented mash of malted cereals, or from malt with unmalted cereals, and containing the congeneric substances formed with ethyl alcohol which are volatile at the ordinary temperatures of distillation and which give the character to the distillate." A mixture of two or more whiskies, as thus defined, irrespective of their source or mode of distillation, and age or environment since distillation, would be a blended whisky, provided each article entering into the combination, standing alone, would be appropriately designated as whisky. Further, the mixture of a spirit properly designated as whisky with another spirit, such as ethyl alcohol, which, standing alone, is not a whisky, should be called a compounded whisky. For mixtures of ethyl alcohol, either pure or mixed with water, with harmless colouring or flavouring agents intended to impart the appearance and flavour of whisky, the term "imitation whisky" should be used. On these or similar lines, an attempt is being made to control the sale of

whisky and other spirits in the United States, under the new pure food law; it is desirable that a corresponding effort be made in this country.

Gin, in this country, is usually made from a mixture of malt and barley, flavoured not only with juniper berries, but with oil of turpentine, orange peel, and several other aromatic substances. In Holland, it is made from unmalted rye and barley malt with juniper berries. In consequence of the juniper and turpentine contained in gin, it is a direct stimulant to the kidneys. It usually contains from 40 to 50 per cent. of alcohol. Its chief adulteration is water, which makes it turbid; to remove this, alum and acetate of lead are employed, followed by the addition of sugar and cayenne pepper to sweeten it and give it pungency. Speaking generally, gin is the spirit of which most is annually consumed by the public, and the spirit which is most often adulterated.

Rum is a spirit obtained by distillation from the fermented skimming of sugar-boilers or the drainings of sugar barrels (molasses). Like brandy, it is colourless when first distilled, but it is, later on, artificially coloured with burnt sugar. The peculiar flavour of rum is due to butyric ether and a volatile oil; the amount of alcohol present in rum is from 50 to 60 per cent. An imitation flavouring identical with that of the Jamaica rum, so often flavoured with slices of pine-apple, is made by distilling butter with sulphuric acid and alcohol, and then, by means of the resulting butyric compound, a fictitious rum can be made from malt or molasses spirit.

When quite pure and free from water, alcohol is termed *absolute alcohol*, having a specific gravity, at 60° F., of 0·79381; when mixed with 10 per cent. by volume or 14·35 per cent. by weight of water, it is called *rectified spirit*, and when mixed with 42·95 per cent., volume in volume of water, it constitutes *proof spirit*.

Proof Spirit is a term constantly in use for excise purposes, signifying a dilute spirit of definite strength. If expressed as volume in volume, proof spirit contains 57·05 per cent. of absolute alcohol; if as weight in weight, 49·25 per cent.; if as weight in volume, 42·46 per cent.; the remainder in each case being distilled water. The ratio of alcohol to proof spirit in each of these cases being, for volume in volume, as 1 is to 1·753; for weight in weight, as 1 is to 2·03; and for weight in volume, as 1 is to 2·355. We can, therefore, if in any case the percentage of contained alcohol be known, calculate the amount of proof spirit present by multiplying the given percentage of alcohol by any of the foregoing ratios.

Spirits which are weaker than proof are described as being *under proof*; when stronger than proof, as being *over proof*. Thus, say a sample of whisky is found to contain 70 per cent., volume in volume, of alcohol; then $70 \times 1{\cdot}753 = 122{\cdot}7$, and the excess of this product over 100, or 22·7, gives the number of degrees over proof of the sample. If, on the other hand, it contained but 24 per cent. of alcohol, volume in volume, then $24 \times 1{\cdot}753 = 42{\cdot}07$, and by just so much as this figure is greater or less than 100, so is the sample degrees over or under proof, that being, in this case, just 57·93 under proof. Conversely, if the degree of strength of any spirit over or under proof be known, the percentage of alcohol present can be calculated either as volume in volume, weight in weight, or weight in volume. Thus, say a sample of brandy be x degrees over proof; then $\frac{100+x}{1{\cdot}753}$ gives the percentage, volume in volume, of alcohol which it contains. If it be x degrees under proof, then $\frac{100-x}{1{\cdot}753}$ gives the percentage, volume in volume, again of alcohol.

The Sale of Food and Drugs Amendment Act, 1879, allows brandy, whisky or rum to be 25 degrees under proof; equal to 42·8 per cent. of absolute alcohol, volume in volume, or 31·8 per cent. of weight in volume. This gives a specific gravity of 0·947. Gin is allowed to be 35 degrees under proof, equal to 37·7 per cent., volume in volume, or 28·1 per cent., weight in volume, of absolute alcohol. This gives a specific gravity of 0·9563. Proof spirit contains 57·05, volume in volume, or 42·46, weight in volume, of absolute alcohol, sp. gr. 0·9198, or 49·25 weight in weight per cent.

Although the alcohol in spirits can be determined by means of the specific gravities before and after de-alcoholisation, as explained for beer and wines, still the strength of spirits is frequently ascertained by the use of Sikes' hydrometer, and a book of tables for its employment.

A sample of the spirits to be tested is poured into a trial glass, and the temperature ascertained by means of a thermometer in the usual way. The hydrometer is taken, and one of the weights is attached to the stem below the ball; it is then pressed down to the 0 on the stem. If the right weight has been selected it will float up to one of the divisions on the stem. The number on the *stem* is then read off and added to the number on the *weight*; the sum is called the *indication*. The book of tables is then opened at the temperature first found, and the indication looked for in one of the columns: opposite it will be found the strength of the spirits *over* or *under* proof. If at the temperature 60° F. the *indication* is 58·8, then opposite this will be found zero, that is, the spirit is the exact strength of *proof*. If the indication is 50, then opposite that is 12·8 or the spirit is 12·8 *over* proof; if the indication is 70, then opposite is 18·9 or the spirit is 18·9 *under* proof. The meaning of these expressions is:—(1) If the spirit be 12·8 over proof then, in order to reduce it to proof, 12·8 gallons of water must be added to 100 gallons of the spirit—the resulting mixure will be proof; (2) if the spirit be 18·9 under proof, this means that 100 gallons contain only as much alcohol as 81·1 (*i.e.*, 100 − 18·9) of proof spirit; to raise it to proof it would have to be mixed with an equal quantity of spirit as much above proof as it is below it, so that $\frac{100-18{\cdot}9+118{\cdot}9}{2}=100$.

The presence of sugar or extractives renders the use of the hydrometer fallacious unless the spirit is distilled off and the instrument then used on the distillate.

THE DIETETIC USE OF ALCOHOL AND ALCOHOLIC BEVERAGES.

In endeavouring to determine the dietetic value of alcoholic beverages, it is desirable to see, in the first place, what are the effects of the most important constituent, namely, alcohol.

Three sets of arguments have been used in discussing this question, drawn, namely, from—(1) the physiological action of alcohol; (2) experience of its use or abuse; and (3) moral considerations.

The last point will not be further alluded to, for without underrating the great weight of the argument drawn from the misery which the use of alcohol produces, this part of the subject is so obvious that it seems unnecessary to occupy space with it. The arguments, however, which are strongest for total abstinence are drawn from this class. All statistics from life assurance offices and other provident institutions put this in a very strong light.

The physiological argument for the use or disuse of alcohol requires to be used with caution, as our knowledge of the action of pure alcohol (much more of the alcoholic beverages) is imperfect.

When taken into the stomach, alcohol is absorbed without alteration, or is perhaps in some small degree converted into acetic acid, possibly by the action of the mucus or secretion of the stomach. The rate of absorption is not known, and it has been supposed that when given in very large quantities it may not be absorbed at all. It has not, however, been recovered from the fæces in any great amount. After absorption it passes into the blood, and, according to Schmiedeberg, forms a compound with hæmoglobin, which more readily gives off oxygen than hæmoglobin itself. The result of this is that alcohol lessens oxidation in the blood and tissues. Most of the alcohol taken is oxidised in the body, the products being excreted in the urine. In dietetic doses, some of the alcohol may be detected in the expired air, but it can be detected in the urine only when the dose is excessive. The presence of alcohol in the urine is therefore, to some extent, a chemical test of an excess of alcohol having been taken.

Alcohol, in healthy persons, increases the force and quickness of the heart's action. It further tends to increase the blood pressure, and to increase the flow of blood from the arteries into the veins. The effect on the blood pressure is, however, largely counterbalanced by a coincident dilatation of the cutaneous blood-vessels.

In most persons, alcohol appears to act at once as an anæsthetic, lessening also the rapidity of impressions, the power of thought, and general acuteness and the perfection of the senses. In other cases it seems to cause increased rapidity of thought, and excites imagination, but even here the power of control over a train of thought is lessened. In almost all cases moderate quantities cause a feeling of comfort and exhilaration, which ensues so quickly as to make it probable that the local action on the nerves of the stomach has at first something to do with this. Afterwards the increased action of the heart may have an effect. Different spirits act differently on the nervous system, owing probably to the presence of the ethers and oils. Absinthe appears especially hurtful, apparently from the presence of the essential oils of anise, wormwood, and angelica, as well as from the large amount of alcohol.

In spite of much experience, it is uncertain whether alcohol really increases mental power. The brain circulation is no doubt augmented in rapidity; the nervous tissues must receive more nutriment, and for a time must work more strongly. Ideas and images may be more plentifully produced, but it is a question whether the power of clear, consecutive, and continuous reasoning is not always lessened. In cases of great exhaustion of the nervous system, as when food has been withheld for many hours and the mind begins to work feebly, alcohol revives mental power greatly, probably from the augmented circulation. But, on the whole, it seems questionable whether the brain finds in alcohol a food which by itself can aid in mental work.

How far alcohol sensibly lowers the temperature of the body in health is still a matter of dispute, but there is no doubt that in some cases of fever, especially in children, alcohol does lower the temperature. Lauder Brunton has suggested that, in health, it tends to lower the body temperature in two ways :—First, in medium doses, "by dilating the cutaneous vessels, whereby more blood comes to the surface of the body, and thus more heat is lost by radiation and by means of the increased perspiration; second, when given in large doses, by lessening the processes of oxidation in the

body." Although there are doubts whether alcohol really lowers the temperature of the healthy body there is no doubt whatever that it lowers the natural resistance of the body against cold. "When a person is exposed to extreme cold for long periods, as in the Arctic regions, he may derive some temporary comfort and sensation of warmth from taking alcohol; but his power of resistance to the intense cold is lessened, and instances have been recorded where death has occurred under such conditions during sleep."

Under circumstances of great heat, the evidence is almost equally conclusive against the use of spirits or beverages containing much alcohol. It seems quite certain, also, that not only is heat less well borne, but that heat-stroke is predisposed to.

When there is want of food, it is generally considered that alcohol has a sustaining force, and possibly it acts partly by keeping up the action of the heart, and partly by deadening the susceptibility of the nerves. It was formerly supposed that it lessened tissue-change, and thus curtailed the waste of the body; but this is not true of the nitrogenous tissues, and it is not yet quite certain in respect of the carbonaceous.

Some light on certain physiological processes which result, in a comparatively short space of time, from doses of alcohol so small that no indications of intoxication are observed, has been shown by the studies of Hunt * in experimental alcoholism. He investigated the effect of alcohol in causing an increased oxidation of certain substances, particularly acetonitrile or methyl cyanide. In the organism, this substance slowly forms thiocyanic acid. Hunt's experiments, which were made on mice, show that animals to which alcohol has been administered for some time acquire an increased susceptibility to acetonitrile. This occurs after the administration of amounts of alcohol far too small ever to cause indications of intoxication, and from doses which certainly cause no anatomical lesions. This increased susceptibility is not due to a general lowering of resistance, but is associated with a distinctly increased power of the body to break up the molecule of acetonitrile. In this series of experiments it was found that mice which had received alcohol, administered by pouring it upon the food, died from about one-half the amount of acetonitrile that was required to kill mice which had not received alcohol. The experiments show, further, that there is something special about the poisonous action of alcohol, inasmuch as certain other poisons—like chloral hydrate and amyl alcohol—which cause a loss of weight and so conceivably lower the general resistance, do not have this effect. Other experiments indicate that mice fed upon oats and dextrose show a very distinct resistance to acetonitrile, often recovering from two or even three times the dose which was fatal to controls. These results afford evidence that in some respects the action of alcohol as a food is different from that of carbo-hydrates, and also that in all probability certain physiological properties in moderate drinkers are different from those in abstainers. These experiments are of extreme interest because of the clear demonstration which has been made in recent years that alcohol is oxidised in the body and may replace fats and carbo-hydrates, and to a certain extent the proteins of an ordinary diet. The drift of modern opinion is certainly towards the view that alcohol is in all respects analogous to sugars and fats, provided always that the amount used does not exceed that which can be easily oxidised by the body. If this be so, it would be expected that alcohol in a diet would have the same effect upon an animal's susceptibility to

* Hunt: *Studies in Experimental Alcoholism*. Bulletin No. 33, Hygienic Laboratory, United States Public Health and Marine Service, Washington, February 1907.

acetonitrile as has, for example, dextrose. But this is by no means the case. While Hunt's experiments are not sufficient to justify the conclusion that in many cases alcohol has not a true food value, yet they are sufficient to indicate caution in applying to practical dietaries without further investigation the results of Chittenden and others as to the protein-sparing power of alcohol.

The question arises: Is alcohol desirable as an article of diet in health? This is a matter of the highest importance, and the answer depends largely upon the reply to another question: When is the limit of the useful effect of alcohol reached? Anstie's experiments showed that an amount of 1½ fluid ounce (42·6 c.c.) caused the appearance of alcohol in the urine.* Parkes and Wallowicz obtained similar results. When only 1 fluid ounce of absolute alcohol was given, none could be detected in the urine. They found that in a strong healthy man, accustomed to alcohol in moderation, the quantity given in twenty-four hours that begins to produce effects which can be considered injurious is something between 1 fluid ounce (=28·35 c.c.) and 2 fluid ounces (56·7 c.c.). The effects which can then be detected are slight, but evident narcosis, lessening of appetite, increased rapidity in the action of the heart, greater dilatation of the small vessels as estimated by the sphygmograph, and the appearance of alcohol in the urine. These effects manifestly mark the entrance of that stage in the greater degrees of which the poisonous effects of alcohol become manifest to all.†

The recent researches of Rosemann and Neumann in Germany, Atwater ‡ and Benedict in America, and Goddard § in this country confirm largely these results. Their experiments indicate that when alcohol to the amount of $\frac{1}{750}$th part of the body weight is administered, a bare 5 per cent. of that amount is excreted, and since no aldehyde or other alcohol derivatives are found in the expired air, in the urine, blood or in any part of the body, we may conclude that 95 per cent., or the remainder, is made use of as a food. If double the quantity of alcohol be administered, some 6 per cent. is excreted, and acetic aldehyde is capable of detection in the expired air. If a still larger dose be given, rather more than 49 per cent. of alcohol or its derivatives is excreted, in other words, there is an absolute failure on the part of the animal body to utilise about half of the quantity of alcohol administered. Alcohol, therefore, in small doses is undoubtedly a food; but since when large doses are taken quite 50 per cent. is excreted, it cannot then be considered a true food, and if still larger quantities be taken this contention applies with even greater force.

Assuming the correctness of these experimental data, which, though not extensive, are yet apparently exact, it is evident that moderation must be something below the quantities mentioned; and considering the dangers of taking excess of alcohol, it seems wisest to assume 1 to 1½ fluid ounce of absolute alcohol in twenty-four hours as the maximum amount which a healthy man should take. It must be admitted that this is provisional, and that more experiments are necessary; but it is based on the only safe data we possess. One ounce is equivalent to 2 fluid ounces of brandy (containing 50 per cent. of alcohol); or to 5 ounces of the strong wines (sherries, &c., 20 per cent. of alcohol); or to 10 ounces of the weaker wines (clarets

* Anstie: "On the Elimination of Alcohol from the Body," *Practitioner*, xiii. 15, 1874.

† Parkes: "On the Elimination of Alcohol from the Body," *Proc. Roy. Soc. Lond.*, Nos. 120, 123, and 136, 1875.

‡ Atwater: "Regarding the Nutritive Value of Alcohol," *Nat. Acad. of Sciences*, vol. viii. Mem. 6, 1902.

§ Goddard: *The Lancet*, October 22, 1904.

and hocks, 10 per cent. of alcohol); or to 20 ounces of beer (5 per cent. of alcohol). If these quantities are increased one-half, $1\frac{1}{2}$ ounce of absolute alcohol will be taken, and the limit of moderation for strong men is reached. This standard appears to be fairly correct. Women, no doubt, ought to take less; and alcohol in any shape only does harm to healthy children.

Another question now arises, to which it is more difficult to reply. Is alcohol, even in this moderate amount, necessary or desirable? A variety of considerations make it difficult to avoid the conclusion that the dietetic value of alcohol has been much overrated. It does not appear possible at present to condemn alcohol altogether as an article of diet in health, or to prove that it is invariably hurtful, as some have attempted to do. It produces effects which are often useful in disease and sometimes desirable in health, but in health it is certainly not a necessity, and many persons are much better without it. As now used by mankind it is infinitely more powerful for evil than for good; and though it can hardly be imagined that its dietetic use will cease in our time, yet a clearer view of its effects must surely lead to a lessening of the excessive use which now prevails.

In the previous remarks, the effect of alcohol only has been discussed, but beer and wine contain other substances besides alcohol.

In beer there appear to be four ingredients of importance, viz., the extractive matters and sugar, the bitter matters, the free acids, and the alcohol. The first, no doubt, are carbo-hydrates, and play the same part in the system as starch and sugar, appropriating the oxygen, and saving fat and proteins from destruction. Hence one cause of the tendency of persons who drink much beer to get fat. The bitter matters are supposed to be stomachic and tonic; though it may be questioned whether we have not gone too far in this direction, as many of the highest priced beers contain now little else than alcohol and bitter extract. The action of the free acids is not known; but their amount is not inconsiderable; and they are mostly of the kind which form carbonates in the system, and which seem to play so useful a part. The salts, especially potassium and magnesium phosphates, are in large amount.

In wine there are some protein substances, much sugar (in some wines), and other carbo-hydrates, and abundant salts. Whether it is that the amount of alcohol is small, or whether the alcohol be itself, in some way, different from that prepared by distillation, or whether the co-existence of carbo-hydrates and of salts modifies its action, certain it is that the moderate use of wine, which is not too rich in alcohol, does not lead to those profound alterations in the structure and functions of organs which follow the use of spirits, even when not taken in excess. Considering the large amounts of vegetable salts which most wines contain, it may reasonably be supposed that they play no unimportant part in giving dietetic value to wine. Indeed, it is quite certain that, in one point of view, they are most valuable; they are highly anti-scorbutic.

In spirits, alcohol is the main ingredient, chiefly in the form of ethyl-alcohol, though there are small amounts of propyl-, butyl-, and, in some cases, amyl-alcohols. In addition, there are sometimes small quantities of ether; and, in some cases, essential oils (as apparently in absinthe), which have a powerful action on the nerves. But spirits are, for the most part, merely flavoured alcohol, and do not contain the ingredients which give dietetic value to wine and beer. They are also more dangerous because it is so easy to take them undiluted, and thus increase the chance of damaging the structure and nutrition of the tissues with which they come first in contact. There is every reason, therefore, to discourage the

use of spirits, and to let beer and wines, with moderate alcoholic power, take their place.

Some of the undoubtedly deleterious effects of crude spirits must be ascribed to the presence of furfurol and other bodies, which both diminish in quantity and change in quality, as the spirit "mellows" with age. These substances, as present in new spirit, tend to derange digestion, and also appear to have a profound effect upon the nervous system.

TEA.

Tea consists of the dried leaves of a shrub called the *Camellia thea*, which grows in China, India, Ceylon, and Japan. As met with in everyday life, tea-leaves are curled, but they uncurl on being placed in hot water, and when so treated are found to have a characteristic shape and structure. The border is serrated nearly, but not quite to the stalk; the primary veins run out from the midrib nearly to the border, and then turn in, so that a distinct space is left between them and the border. The leaf may vary in point of size and shape, being sometimes broader, and sometimes long and narrow. The border and the primary venation distinguish it from all leaves (Fig. 48). The leaves which it is said have been mixed with or substituted for tea in this country are the willow, sloe, oak, Valonia oak, plane, beech, elm, poplar, hawthorn, and chestnut; and in China *Chloranthus inconspicuus* and *Camellia Sasanqua* are said to be used. Of these the willow and the sloe are the only leaves which at all resemble tea-leaves. The willow is more irregularly, and the sloe is much less perfectly and uniformly, serrated.

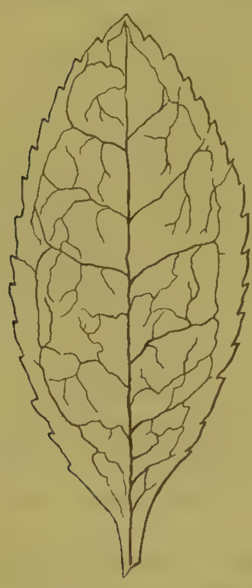


FIG. 48.—LEAF OF THE CAMELLIA THEA.

To examine the leaves, make an infusion, and then spread out a number of leaves; if a leaf be placed on a glass slide, and covered with a thin glass, and then held up to the light, the border and venation can usually be well seen. The leaves of the Valonia, if used, are at once detected by acicular crystals being found under the microscope.

Sometimes exhausted tea-leaves are mixed with catechu or with a coarse powder of a reddish brown colour, consisting chiefly of powdered catechu. Gum and starch are added, the leaves being steeped in a strong solution of gum, which, in drying, contracts them. The want of aroma, and the collection at the bottom of the infusion of powdered catechu, or the detection of particles of catechu, will at once indicate this falsification, which is, however, very uncommon.

Practically all tea in the market is grown from the same species of shrub; the various names given as indicating different kinds are only trade names, and do not indicate really different varieties of tea-leaf so much as different qualities dependent upon mixing or blending, and on the age of the leaves, or on the soil on which the plant has been grown. In all cases, the leaf most highly valued is the small top leaf of the twig and the bud. Possibly these small leaves are neither finer in quality nor richer and better in flavour than the leaves next in succession, but being more tender and softer in structure give better and more flavoured infusions. The various teas known under the trade names of Orange Pekoe, Pekoe, Suchong, Congou are all the

same in respect of origin; they are picked at the same time from the same shrub. The bud and top leaf constitute Orange Pekoe, the two or three larger leaves growing on the same twig a little lower down are Suchong, and below that the leaves become Congou.

The most simple division of teas is into the green and the black; both are from the same plant, the only difference is their colour. Green tea is now little used, in consequence of the disrepute into which it fell as the result of the artificial colouring it received; but real green tea owes its coloration to being dried over wood fires when fresh. Black teas owe their colour to the leaves having been allowed to lie in heaps for twelve hours, during which they undergo a process of fermentation and are afterwards dried slowly over charcoal fires. "Brick tea" is made from the refuse, broken leaves and twigs, moulded into shapes. In selecting a fine tea, one should not be guided by any trade name, but determine, by pouring a little boiling water over the leaves and examining them, whether the leaf was a whole leaf and not a large leaf cut into small pieces. The larger the leaf, the weaker will be the infusion and the less the value.

The average percentage composition of tea may be expressed as follows:—

Water	8·0	
Thein	2·6	
Tannin	14·0	
Oil	0·4	
Extractives	15·0	
Insoluble organic matter	54·0	
Ash	6·0	Potash, iron, silica, alumina, magnesia.

There is rather more tannic acid, and more thein and ethereal oil, in green than black tea, but less cellulose; otherwise the composition is much the same.

The most essential points in making good tea of the finest quality, and with the least waste, are to have actually boiling water, and tea-leaves so crushed and subdivided that the largest possible surface is rapidly exposed to the boiling water in infusing it. This explains why the best tea infusion in the world is that made by the Japanese from their carefully prepared "tea powder," which is made by crushing to a fine powder certain well-selected leaves. The tea bricks of China probably owe their superiority to being well-crushed leaves of good quality. About $\frac{9}{10}$ths of the soluble matters in the tea-leaves are taken up by the first infusion with hot water.

If water contains much lime or iron it will not make good tea; in each case the water should be well boiled with a little carbonate of soda for fifteen or twenty minutes, and then poured on the leaves.

In the infusion are found dextrin, glucose, tannin, and thein. About 47 per cent. of the nitrogenous substances pass into the infusion, and 53 per cent. remain undissolved. If soda is added, a still greater amount is given to water. The amount of tannin taken up by the infusion varies according to the character of the tea as well as the time the infusion is allowed to stand.

As an Article of Diet, tea seems to have a decidedly stimulant and restorative action on the nervous system, followed by no after-depression. This effect is mainly due to the alkaloid thein which it contains, aided, perhaps, by the warmth of the infusion. Thein or caffein is chemically tri-methyl xanthin or methyl theobromine, $C_8H_{10}N_4O_2$. Though considered to be chemically identical with caffein, thein differs somewhat from it in physiological action. After taking tea, the pulse is a little quickened, the action of the skin increased, and that of the bowels lessened. The kidney excretion is little affected, at most the urea is slightly diminished, but the evidence

with respect to this is somewhat contradictory. Roberts has shown that tea retards both salivary and peptic digestion, and it is probable that most of the symptoms resulting from excessive consumption of tea are those of delay of digestion, that is, of food remaining undigested in the stomach. A prevalent idea is that the tannin, in tea, chiefly produces the disturbances of digestion so commonly associated with abuse of tea ; according to Roberts, however, it is not clear what constituent of tea is the really active agent in producing dyspepsia.

Examination of Tea.—Judge of the aroma of the dry tea and its infusion ; spread out the leaves and see their characters ; collect anything like mineral powder and examine under microscope. The microscope will also show if the tea has deteriorated by keeping ; sometimes *acari* and *fungi* may be found.

The tea should not be too much broken up, or mixed up with dirt. Spread out, the leaves should not be all large, thick, dark, and old, but some should be small and young. There will always be in the best tea a certain amount of stalk and some remains of the flower. In old tea much of the ethereal oil has evaporated, and the aroma is less marked.

The infusion should be fragrant to smell, not harsh and bitter to taste, and not too dark. The buyers of tea seem especially to depend on the smell and taste of the infusion.

Formerly, the chief adulteration of tea was by mixing with it other leaves, such as those of the sloe and willow, which have a superficial resemblance to tea-leaves. At the present time the chief adulteration of tea is the admixture of old and exhausted tea-leaves, while in the inferior kinds there is often clay, lime, or ferruginous sand. The total soluble matters obtainable from tea are a ready and convenient index of its quality ; they are estimated by infusing a weighed quantity with an excess of distilled water, and evaporating this down to dryness ; the amount of extract so obtained should be at least 30 per cent. If the sample contain many exhausted leaves, the amount of extract obtained will be, of course, less.

To make the infusion, take 10 grammes of tea, and infuse in 500 c.c. of *boiling* distilled or rain water. Let it stand five or six minutes before smelling and tasting it. Exhaust the leaves by boiling with successive portions of water, until no colour is given up to the water. Measure the total amount of the infusion and decoction mixed together ; take 100 c.c. and dry it in a water-bath, and weigh. Calculate out the percentage. The sp. gr. of the infusion will be found, if made from a good tea, to vary from 1011 to 1015.

The exhausted leaves may also be dried and weighed, the loss representing the amount of extract, which ought to correspond with the amount obtained by direct estimation.

The ash should also be determined ; 5 or 10 grammes are to be incinerated ; the ash is generally grey, sometimes slightly greenish. Any excess above 6 per cent. is suspicious ; if above 8 per cent. on the *perfectly dry tea*, adulteration is certain. About one-half of the ash is soluble in water ; the solution is often (but not always) pink, from the presence of manganese. The amount and character of the ash form good means of detecting the use of exhausted leaves.

The acidity of the infusion, and the amount of tannin and thein, may also be determined ; also the chlorine, alkalinity, and iron of the ash. The best tests of the *quality* of the tea are the aroma and the physical characters.

Extraction of Thein.—Occasionally it may be desired to determine the quantity of thein. Take 100 grammes of tea, exhaust with boiling water,

and add some solution of subacetate of lead; filter; wash with sulphuric acid (1 in 4) to get rid of excess of lead; filter; evaporate to small bulk, and add a little ammonia; add more water, decolorise with animal charcoal, and evaporate slowly to small bulk. White feathery crystals of thein form, which should be collected on filtering paper, dried at a very low heat, and weighed.

COFFEE.

Coffee is the seed or berry of the *Caffea Arabica*, a plant growing in most parts of the tropics, but chiefly in Arabia, Abyssinia, Ceylon, and the West Indies. After the seeds have been roasted to a chocolate brown, they are ground to a powder in a mill, and then used in the form of a decoction or infusion. The percentage composition of unroasted coffee may be expressed as follows:—

Water	11·23
Nitrogenous matter	12·07
Caffein	1·21
Fat	12·27
Sugar or dextrin	8·55
Tannin	32·79
Cellulose	18·17
Salts	3·71

The chief properties of coffee depend upon an aromatic oil and the alkaloidal body, caffein. Caffein itself is a nitrogenous crystalline alkaloid, identical with thein; in the roasting of coffee, this body is not destroyed, but dissociated, as it were, from its previously existing combination with tannin. During the same process, the sugar and dextrin are changed into caramel, and the gas and water of the berry driven off.

Recent researches in Madagascar by Bertrand show that in that and the adjacent islands beans of a species of coffee exist which contain no caffein, but merely a resinous bitter called "cafamarine." These facts are interesting as bearing upon the accepted rule that the presence of caffein is a proof of genuine coffee.*

As an Article of Diet, coffee stimulates the nervous system, and in large doses produces tremors. Caffein given to animals augments reflex action, and may produce tetanic spasms, or peculiar stiffness of muscles. It increases the frequency of the pulse in men (but taken in large quantity diminishes it), and removes the sensation of commencing fatigue during exercise. It has been said to lessen the excretion of urea and phosphoric acid, but this is doubtful. It appears, however, to increase the urinary water.

To make good coffee the berry must be freshly roasted. Good drinkable coffee requires as much as an ounce of recently roasted and ground coffee to each large cup, the result of which means that the cost of a cup of good coffee, including milk and sugar is about twopence. The prevalent custom in making coffee in this country is to use barely an ounce to two pints of water, the resulting infusion being more or less mawkish, tasteless, and wanting in stimulating properties.

Detection of Adulterations.—The chief adulterant of coffee is chicory, but at times dates, beans, maize, and acorns have been added. Chicory is a legal addition to coffee, provided such admixture is stated,

* Further information on these caffein-free coffees can be obtained from *Comptes Rendus de l'Acad. des Sciences*, Paris, 1901, cxxxii. p. 162; *also* 1905, cxli. p. 209; also *Bulletin de la Soc. Chimique*, 1906, xxv. p. 379.

no limit being fixed as to their relative proportions; as a rule, it amounts to about 30 per cent. The addition of chicory to coffee is considered by most people to add to its flavour. It is probable that much of the present decadence of coffee-drinking is due to want of care in its preparation, and the excessive addition of chicory, whereby the resulting infusion is wanting in the desired alkaloid caffein.

Chicory is the dried and powdered root of the wild endive (*Cichorium intybus*). In composition it differs much from coffee, containing no caffein, less fat, but more sugar. It may be readily distinguished from coffee by the fact that when thrown into water it rapidly sinks and colours the liquid brown, while coffee floats and does not yield any colour. The surest test, however, is microscopical examination, as both the cells and dotted ducts of chicory are quite characteristic; at least nothing like them exists in coffee. The long cells of the testa of coffee berries are equally marked. The interior of the berry also presents characters which are quite evident: an irregular areolar tissue containing light or dark yellow angular masses and oil globules, which are very different from any adulterations. The little corkscrew-like unrolled spiral fibres are chiefly found in the bottom of the raphe.

The percentage of ash has been suggested as a means of detection. Coffee yields about 4 per cent., of which four-fifths are soluble in water; chicory yields 5 per cent., of which only one-third is soluble.

Chicory contains a notable amount of sugar, 10 to 18 per cent., whereas roasted coffee has never more than 1 per cent. Wanklyn has proposed to make this a basis of detection, using the standard copper solution.

Other methods for the estimation of chicory in mixtures of coffee and chicory are based respectively upon the specific gravity of the infusion, and upon the amount of solid extract obtainable from it. Take 10 grammes of the sample, infuse in 100 c.c. of water, boil for half a minute, filter, and after filtrate cools to 60° F., take the specific gravity. The sp. gr. of a 10 per cent. infusion of pure coffee is 1010, that of a similar infusion of pure chicory, 1022; that is, a standard difference of 12 between the two specific gravities.

Next place the filter with the coffee dregs on it into a large flask with 150 c.c. of water. Stir gently, boil for five minutes, allow sediment to subside, filter off the supernatant liquid and add filtrate to the original filtrate obtained above. Allow to cool, measure, and make up with distilled water to 250 c.c.; mix the whole thoroughly, then pipette 50 c.c. (=2 grammes of the sample) of this infusion into a weighed capsule. Evaporate to dryness over a water-bath, re-weigh, and calculate solid extract as a percentage.

Treated as above, chicory gives a mean percentage extract of 70; while coffee gives a remarkably constant percentage extract of 24; or a standard difference of 46. Consequently, we have percentage of coffee

$$= \frac{100\ (70 - \text{percentage of extract found})}{46}.$$

Roasted corn or beans are at once known by the starch grains, which commonly preserve their characteristic form. Iodine turns them at once blue, while the infusion will also give a blue with iodine. Potato and sago starch are sometimes added, but their presence is easily detected by the microscope. The presence of sugar can be readily estimated by the standard copper solution; if caramel has been added, the extract will be found to be brittle, dark coloured, and bitter to the taste.

Occasionally, chicory itself is adulterated with mangel-wurzel, parsnip, carrot, acorn, or sawdust. The cells of mangel-wurzel are like chicory, but much larger; those of carrot and parsnip are something like chicory, but

contain starch cells; the starch grains of the acorn are round or oval, with a deep curved depression, or hilum. The infusion of chicory is not turned blue by iodine; when incinerated the ash of chicory should not be less than 5 per cent.

PARAGUAY TEA, KOLA AND COCA.

Paraguay Tea, sometimes known as *maté*, is obtained by roasting the leaves of *Ilex paraguayensis* and exposing them to the action of the sun. It is much used in various parts of South America. The mean of several analyses of dried *maté* show it to contain 3·87 per cent. of proteins, about 3 per cent. of fats and resinous oil, 2·38 per cent. of sugar, 3·92 per cent. of salts, about 1 per cent. of thein and 4 per cent. of tannin. About 24 per cent. of the solids are soluble in water. Its infusion has an action similar to other thein-containing beverages, but is more apt, it is said, to cause digestive disturbance.

Closely allied to Paraguay tea is **Guarana**, obtained by roasting the seeds of *Paullinia sorbilis*. It contains nearly 5 per cent. of thein or caffein, and has some medicinal value in migraine.

Kola is prepared from the seeds of the *Sterculia acuminata*, a tree resembling the chestnut and growing wild on the west coast of Afr ca. Its percentage composition is as follows:—Water 11·9, proteins 6·7, fat 0·68, starch and sugar 36·5, caffein 2·42, tannin 1·6, cellulose 33·7, ash 6·5. It is therefore closely allied to tea and coffee, but differs from them in the relatively large amount of alkaloid which it contains. Kola nuts are hard and irregularly shaped, of a reddish brown colour, and present a faintly aromatic odour. When powdered, their taste is bitter, leaving a harsh and earthy flavour on the palate.

Kola has some slight fatigue-dispelling power, if masticated, or taken when freshly ground in the form of an infusion like coffee. It increases the urinary water, and reduces the total solids of the urine, especially the extractives; it acts as a stimulant to the nervous system, and increases arterial tension; its stimulating and sustaining qualities are, however, largely overrated. True kola nuts are somewhat difficult to obtain; many of these nuts now in the market are not those of *Sterculia acuminata*, but those of *Garcinia kola* and *Sterculia cordifolia*, species which do not contain caffein, and which, consequently, are more or less without any physiological action.

Coca, from the leaves of *Erythroxylon coca*, when chewed, is said to have a similar action to that claimed for kola, namely, to take away the feeling of fatigue after and during excessive exertion. It is much used as a stimulant in Peru, and contains the alkaloid cocaine, the use of which as a local anæsthetic is well known. Some observations upon the sustaining and stimulating properties of coca-leaves have been made on soldiers, both during and after long marches, but with only indifferent success. The ill-success which has attended various attempts to use both kola nuts and coca leaves, by Europeans, as stimulants during unusual bodily exertion, is probably due to the fact that the normal diet of Europeans is rich in stimulant extractives of the xanthin group. Consequently, the consumption of substances, however rich in caffein, by them, would have less effect than on the indigenous races of Africa or South America, whose ordinary dietary is of a less stimulating character.

COCOA AND CHOCOLATE.

Cocoa is the roasted seed of the *Theobroma cacao*, growing chiefly in the West Indies. Cocoa nibs are the seeds or beans roughly broken ; flake cocoa is the same completely ground and crushed ; soluble cocoa is similar, but the percentage of natural salts has been increased ; while prepared cocoa is the same after half or more of its contained oil or fat has been removed, and in most cases starch and sugar added. Excepting those cocoas which are admittedly mixed with foreign substances, the cocoas of the leading firms show the following ranges in composition :—

Water	from 13 to 8	per cent.
Nitrogenous matter	,, 19 ,, 20	,,
Fat	,, 26 ,, 31	,,
Mineral matters	,, 4 ,, 8	,,
Starch	,, 3 ,, 7	,,
Cellulose	,, 6 ,, 7	,,
Other nitrogen bodies	,, 29 ,, 31	,,
Theobromine	,, 1 ,, 2	,,

There are practically two classes of cocoa on the English market, one which is pure cocoa simply roasted, ground and the fat expressed ; the other in which the natural salts have been increased in order to raise the true solubility of the cocoa. The cocoas of the former class exhibit commonly an acid reaction, and those of the latter class either a neutral reaction or a slightly alkaline one due not to free alkali, but to the presence of alkaline salts. Cadbury's cocoa may be taken as a type of the first class, and Van Houten's cocoa as a type of the other, while Plasmon cocoa represents a neutral or slightly alkaline cocoa containing 60 per cent. added dried milk protein. The following analyses show the respective solubilities of these cocoas in boiling water ; * the total protein of the cocoas respectively being 18·6 per cent., 17·25 per cent., and 54·43 per cent., or in other words, Plasmon cocoa yields to boiling 70 per cent. of its protein, Van Houten's 60 per cent., and Cadbury's 33 per cent.

	Total dissolved matters.	Dissolved mineral salts.	Dissolved organic matter.	Dissolved protein.
Cadbury's	19·30	3·20	16·60	5·90
Van Houten's	23·00	5·20	17·80	10·55
Plasmon cocoa	50·40	5·00	45·40	38·21

The various cocoa pastes, particularly those issued in the Navy and Army, contain 50 per cent. of pure cocoa nibs, containing the whole of the natural cocoa butter, 20 per cent. of refined sugar, 14 per cent. of honey, and 16 per cent. of water.

The active principle of cocoa, theobromine, is closely related to caffein, being dimethylxanthin, $C_7H_8N_4O_2$. Its physiological action is chiefly exerted on the muscular system, and it is a greater restorer of muscular activity than either thein or caffein. Its effect on the nervous system is not well defined.

The adulteration of cocoa is chiefly by the addition of sugar and starch, which the microscope will detect ; while, by some, the removal of the fat, so as to reduce it below 20 per cent., is regarded as an adulteration. Apart from cocoa consisting largely of nitrogenous and fatty matter, in its com-

* "Cocoa Chemically and Physiologically Considered," *Lancet*, 1905, i. pp. 47 and 316.

mercial forms it contains so much starch and sugar that it is rightly regarded to some extent not only as a protein and fatty food, but also a carbo-hydrate. Cocoa differs much from both tea and coffee in having but little stimulant action, but it possesses some nutritive value, and, as such, may in a limited sense be regarded as a food.

The starch grains of cocoa are small and embedded usually in the cells. The presence of starch grains of cereals, arrowroot, sago, or other kinds of starch, is at once detected by the microscope. Sugar can be detected by the taste, and by Fehling's solution. Mineral substances are best detected by incineration, digesting it in an acid and testing for iron, lead, &c.

Chocolate is a preparation of cocoa, from which the greater part of the fat has been removed, and which, after being mixed with sugar and various flavouring substances, is made into a paste with water, and then pressed in moulds.

LEMON AND LIME JUICE.

These juices contain free acids in large quantities, chiefly citric, and a little malic acid, sugar, vegetable albumin, and mucus.

Lemon juice is the expressed juice of the *Citrus limonum*, and lime juice that of the *Citrus limetta*. The British Pharmacopœia directs that lemon juice should have a specific gravity of 1039, and should contain 32·5 grains of citric acid per ounce. The Board of Trade standard for lemon juice is a specific gravity of 1030, when de-alcoholised, and an acidity equivalent to 30 grains per ounce of citric acid. It occasionally may be met with having a density as high as 1050.

Lime juice has usually a less specific gravity than lemon juice, of about 1037 or 1035, and also contains less acid, or about 32·22 grains per ounce.

As found in the Merchant Service, or used in the Royal Navy, the lime or lemon juice is chiefly prepared in Sicily or the West Indies. Sugar is added to it when issued, to make it more agreeable to taste, in the proportion of half its weight. The juice is usually issued in bottles containing from three to four pints, not quite filled, and covered with a layer of olive oil. About 1 ounce of brandy is added to each 10 ounces of juice. Sometimes the juice is boiled, and no brandy is added ; the former kind keeps better. Both are equal in anti-scorbutic power. Good lemon juice will keep for at least three years ; bad juice soon becomes turbid, and then stringy and mucilaginous, while the citric and malic acids decompose, glucose and carbon dioxide being formed. Some turbidity and precipitate do not, however, destroy its anti-scorbutic powers.

As found in the market, it is frequently mixed with water, and sometimes with other acids, such as tartaric and sulphuric acids. The lime juice used in the Arctic Expedition, 1875–6, gave on analysis 27 grains of citric acid per ounce as issued, that is, after being fortified with about 15 per cent. of proof spirit. Before fortifying it contained 32 grains. Some samples which have come under our notice showed a density of 1023 as issued, and of 1035·7 after de-alcoholisation ; the extract was about 8·5 per cent. The unfortified juice froze at 25° F., the fortified remained liquid down to 15° F. Prolonged freezing at a temperature of nearly 0° F. produced no change in the character or amount of the constituents.

In the examination, the points which seem of consequence, in addition to the determination of the free acidity, are the fragrancy of the extract and the alkalinity of the ash, proving the existence of some alkaline citrate. The latter can, however, be imitated, but the fragrancy cannot be so.

Fictitious Lemon Juice.—It is not easy to distinguish well-made fictitious lemon juice. As a rule about 552 grains of crystallised citric acid are dissolved in a wine pint of water, which is flavoured with essence of lemon dissolved in spirits. This corresponds to about 19 or 20 grains of dry citric acid per ounce. The flavour is not, however, like that of the real juice, and the taste is sharper. Evaporation detects the falsification.

Use of Lemon Juice.—In military transports, the daily issue of 1 ounce of lemon juice per head is commenced when the troops have been ten days at sea, and by the Merchant Shipping Act, 1867, the same issue is ordered on merchant vessels, except when the ship is in harbour, and fresh vegetables can be procured. It is mixed with sugar. Of the various substitutes, probably citric acid is the best, or citrate of sodium; then perhaps vinegar, though this is inferior; and lowest of all is citrate of potassium. The tartrates, lactates, and acetates of the alkalies may all be used, but there are no good experiments as to their relative anti-scorbutic powers on record. If milk is procurable, it may be allowed to become acid, and the acid then neutralised with an alkali. The fresh juices of many plants, especially species of cacti, can be used, the plant being crushed and steeped in water; and in circumstances where neither vegetables, lemon juice, nor any of the substitutes can be procured, we ought not to omit the trial of such plants of this kind as may be obtainable.

VINEGAR.

Ordinary commercial vinegar is really a more or less impure acetic acid, containing besides acetic acid, alcohol, acetic ether, sugar, extractive matters, alkaline acetates, and a variable amount of salts. It usually also contains some sulphuric acid, which by law must not exceed $\frac{1}{1000}$th part of its weight of pure acid.

There are four kinds of vinegar commonly in use in Europe. These are Malt Vinegar, Wine Vinegar, Vinegar from starch, sugar, &c., and Wood Vinegar. The acid in all these products is identical, but there are distinct differences of flavour and odour between them. Owing, however, to the addition of colouring-matter and flavouring essences, it is often very difficult to detect the sources of some of the inferior vinegars. All varieties of vinegar, except that obtained by means of the destructive distillation of wood, are formed by the oxidation of alcohol.

Malt vinegar, which constitutes the greater part of the vinegar used in this country, is derived from the acetous fermentation of a wort made from malt and barley. It is of a distinct brown colour, having a specific gravity of from 1016 to 1019. It commonly contains traces of alcohol, 0·4 per cent. of extract, 4 per cent. of acetic acid, and about 0·1 per cent. of sulphuric acid.

Wine vinegar is chiefly used on the Continent, where it is prepared from grape juice and inferior new wines, that made from white wine being the most esteemed. These vinegars vary in colour from straw to red, have usually an alcoholic odour, and a specific gravity of from 1015 to 1022. They usually contain 1 per cent. of alcohol, 1 per cent. of extract, from 5 to 6 per cent. of acetic acid, with small quantities of tartaric acid and tartrate of potash.

The chief adulterations of vinegar are water, mineral acids, especially sulphuric, metals, such as copper, arsenic, lead and tin, pyroligneous acid and various organic substances, such as colouring-agents and capsicum.

The acidity of English vinegar is chiefly caused by acetic and sulphuric

acids, but it is usually calculated at once as glacial acetic acid. If it falls below 3 per cent. water has probably been added. If the specific gravity be low, and the acidity high, excess of sulphuric acid may have been added.

Sodium carbonate or ammonia gives a purplish precipitate in *wine* vinegar but not in *malt* vinegar.

If excess of sulphuric acid be suspected, it must be determined by baryta; this requires care, as sulphates may be introduced in the water. Hydrochloric acid and barium chloride are added; the sulphate of barium collected, dried, weighed, and then multiplied by 0·412, gives the weight of sulphuric acid.

The presence of copper in the vinegar used for pickles may be easily detected by simply inserting the bright blade of a steel knife. Many vinegars, especially the weaker and inferior kinds, often contain, in extraordinary abundance, *Anguillula oxyphila* or vinegar eels, these being minute worms from 1 to 2·5 mm. in length. Beyond rendering the condiment somewhat disgusting to the eye, it is doubtful whether they have any prejudicial effect.

As an Article of Diet, vinegar holds the same rank as the vegetable acids generally. It tends to maintain the alkalinity of the blood and the liquids which bathe the tissues. The acetic acid is largely converted into carbonates in the body, and in doses of from $\frac{1}{2}$ to 1 ounce daily, vinegar is a valuable anti-scorbutic. But this valuable dietetic quality is partly counterbalanced in English vinegar by the unfortunate circumstance that sulphuric acid ($\frac{1}{1000}$th in weight) is allowed to be added to it. This defect is not present in the wine vinegar from the Continent. If taken well diluted with water, vinegar makes a useful and far from disagreeable drink.

MUSTARD.

Mustard is the seed of the *Sinapis alba* and *Sinapis nigra*. Commonly sold as a powder, it is liable to considerable adulteration by being mixed with different varieties of the starches or with turmeric.

Good mustard is known by the sharp acid smell and taste. Its chief adulterations can be usually detected with the microscope. The microscopic characters of mustard seed are well marked. The outer coat of the white mustard consists of a stratum of hexagonal cells, perforated in the centre, and other cells which occupy the centre portion of the hexagonal cells, and which escape through the opening when swollen from imbibition of water. These cells are believed to contain the mucilage which is obtained when mustard is placed in water. There are two internal coats made up of small angular cells; the structure of the seed consists of numerous cells containing oil, but no starch. The black mustard has the same characters without the infundibulum cells.

Pure mustard contains 13·95 per cent. of carbo-hyhrates, 0·66 per cent. of volatile oil, and 35·42 per cent. of fixed oil. In an adulterated mustard, the carbo-hydrates may be as high as 67 per cent. sometimes, and the fixed oils as low as or even below 7 per cent.

PEPPER.

There are two kinds of pepper, the black and the white. Black pepper is obtained from *Piper nigrum*, while white pepper is the same decorticated. Dried black pepper contains about 7·87 per cent. piperin and fixed oil, with

not less than 50 per cent. of carbo-hydrate which is transformable into sugar. This quantity of carbo-hydrate has been suggested as a test for the purity of pepper. In white pepper, the piperin and fixed oil is about 8·24 per cent., and the carbo-hydrates 64·95 per cent., of which 47 per cent. is starch.

The microscopic characters of pepper are rather complicated ; there is a husk composed of four or five layers of cells and a central portion. The cortex has externally elongated cells, placed vertically, and provided with a central cavity, from which lines radiate towards the circumference ; then come some strata of angular cells, which towards the interior are larger, and filled with oil. The third layer is composed of woody fibre and spiral cells. The fourth layer is made up of large cells, which towards the interior become smaller and of a deep red colour ; they contain most of the essential oil of the pepper. The central part of the berry is composed of large angular cells, about twice as long as broad. Steeped in water, some of these cells become yellow, others remain colourless. It has been supposed that the yellow cells contain piperin, as they give the same reactions as piperin does ; the tint, namely, is deepened by alcohol and nitric acid, while sulphuric acid applied to a dry section causes a reddish hue.

White pepper is the central part of the seed, but some small particles of cortex are usually mixed with it. It is composed of cells containing very small starch grains. Hassall says that the central white cells are so hard that they may be mistaken for particles of sand. A little care would avoid this. The starch grains are easily detected, however small, by iodine.

Pepper is adulterated with linseed, mustard husks, wheat and pea flour, rape cake, and ground rice. The microscope at once detects these adulterations.

Pepper dust is merely the sweepings of the warehouses. Rape or linseed cake, cayenne and mustard husks, are mixed with pepper dust, and it is then sold as pepper.

SALT.

The purity of ground salt is known by its whiteness, fine crystalline character, dryness, complete and clear solution in water. The coarser kinds, containing often chloride of magnesium, and perhaps lime salts, are darker coloured, more or less deliquescent, and either not thoroughly crystallised or in too large crystals. In large masses rock salt is often of a reddish colour, which disappears on grinding.

Dietetic Use of the Condiments.—The various condiments owe their action as food accessories to the aromatic oils which they contain. These oils or active principles have practically three kinds of action. In the first place they are *antiseptic*, and by virtue of this property serve to prevent acid fermentation in the digestive tract. They are also *stimulants of digestive juices*, and of *peristaltic action*. Taken in quantity and by themselves, possibly some act as stimulants of the nervous system, but this action is quite independent of their *rôle* as food accessories.

CHAPTER VII

CLOTHING

THE main objects of clothing are :—(1) to protect the body from cold, heat, wind, and rain ; (2) to maintain its warmth, protect it from injury, and also to adorn it.

The subject naturally divides itself into two parts, namely, first a description of the materials of clothing, and second, the principles which should guide us in the selection and construction of clothing.

MATERIALS OF CLOTHING.

The chief materials used for clothing are derived from animals and vegetables. From the animal world we get wool, fur, leather, feathers, and silk ; while from vegetable life we draw cotton, ramie, flax, jute, hemp, coir, india-rubber, and gutta-percha. To these might be added various inorganic bodies, such as iron, steel, brass and glass for buttons, &c.

Although the materials used for clothing are readily recognised by their naked eye and microscopical characters, certain chemical reactions are of value in appreciating the nature of mixed fabrics. They may be thus summarised.

Chemical Reactions.—Wool and silk dissolve in boiling liquor potassæ or liquor sodæ of sp. gr. 1040 to 1050, while cotton and linen are not attacked. Wool is little altered by lying in sulphuric acid, but cotton and linen change in half an hour into a gelatinous mass, which is coloured blue by iodine. Silk is slowly dissolved. Wool and silk take a yellow colour in strong nitric acid ; cotton or linen do not. So also wool and silk are tinged yellow by picric acid ; cotton and linen are not, or the colour is slight and can be washed off. Silk, again, is dissolved by hot concentrated chloride of zinc, which will not affect wool. In a mixed fabric of silk, wool, and cotton, first boil in strong chloride of zinc, and wash ; this gets rid of the silk ; then boil in liquor sodæ, which dissolves the wool, and the cotton is left behind. Another re-agent is recommended by Schlesinger, viz., a solution of copper in ammonia ; this rapidly dissolves silk and cotton, and, after a longer time, linen ; wool is only somewhat swollen by it. By drying thoroughly first, and after each of the above steps, the weight of the respective materials can be obtained.

Wool.—Round fibres, transparent or a little hazy, colourless, except when artificially dyed. The fibres have on their surface imbricated scales which all run in one direction (Fig. 49). These imbrications or serrations cause wool fibres to adhere tightly, and make it difficult to unravel closely woven woollen fabrics. The serrations are most numerous in the fine wools, as many as 2800 per inch being counted. In some inferior wools the serrations are not more than 500 to the inch. When old and worn, the

fibre breaks up into fibrillæ ; and, at the same time, the markings become indistinct. By these characters old wool can be recognised. The size of the fibres varies, but averages from $\frac{1}{1800}$th to $\frac{1}{300}$ inch.

As an Article of Clothing.—Wool is a bad conductor of heat and a great absorber of water ; but it is non-absorbent of odours. The water penetrates into the fibres themselves and distends them, and also lies between them. In these respects it is greatly superior to either cotton or linen, its power of hygroscopic absorption being at least double in proportion to its weight, and quadruple in proportion to its surface.

This property of hygroscopically absorbing water is a most important one. During perspiration the evaporation from the surface of the body is necessary to reduce the heat which is generated by the exercise. When exercise is finished, the evaporation still goes on, and, if unchecked, to such an extent as to chill the frame. When dry woollen clothing is put on after exertion, the vapour from the surface of the body is condensed in the wool, and gives out again the large amount of heat which had become latent when the water was vaporised. Therefore a woollen covering, from this cause alone, at once feels warm when used during sweating. In the case of cotton and linen the perspiration passes through them, and evaporates from the external surface without condensation ; the loss of heat then continues. These facts make it plain why dry woollen clothes are so useful *after* exertion.

Fig. 49.—Wool Fibres.

In addition to this, the texture of wool is warmer, from its bad conducting power, and it is less easily penetrated by cold winds. The disadvantage of wool is the way in which its soft fibre shrinks in washing, and after a time becomes smaller, harder, and probably less absorbent. To avoid this, the greatest care is needed in washing woollen fabrics. Too many articles must not be attempted at once. The best procedure is as follows :— Prepare two vessels containing a sufficiency of hot water in each. In one have a good lather of soap ; into this plunge the article to be washed, avoiding all rubbing of solid soap on to the material, or the use of soda, but cleanse by means of gentle friction in the soapy water. Do this as quickly as possible, and, when all dirt is removed, wring out smartly and transfer to the second vessel containing soap-free hot water. After rinsing thoroughly to extract all soap, wring out, and dry in the open, if possible. Should open-air drying not be feasible, dry in front of a moderate fire, turning and pulling out the article frequently during the drying process. If attention be paid to these details, ordinary woollen goods will keep their shape and elasticity, without shrinkage or hardening.

In the choice of woollen underclothing the touch is a great guide. There should be smoothness and great softness of texture ; to the eye the texture should be close ; the hairs standing out from the surface of equal length, not long and straggling. The heavier the substance is, in a given bulk, the better. In the case of blankets, the softness, thickness, and closeness of the pile, and the weight of the blanket, are the best guides.

In woollen cloth the rules are the same. When held against the light

the cloth should be of uniform texture, without holes; when folded and suddenly stretched, it should give a clear ringing note; it should be very resistant when stretched with violence; the "tearing power" is the best way of judging if "shoddy" has been mixed with fresh wool. A certain weight must be borne by every piece of cloth as indicated by a special testing machine. Schlesinger recommends the following plan for the examination of a mixed fabric containing shoddy:—Examine it with the microscope, and recognise if it contains cotton, or silk, or linen, besides wool. If so, dissolve them by ammoniacal solution of copper. In this way a qualitative examination is first made. Then fix attention on the wool. In shoddy both coloured and colourless wool fibres are often seen, as the fibres have been derived from the different cloths which have been partially bleached; the colouring-matter, if it remains, is different—indigo, purpurin, or madder. The diameter of the wool is never so regular as in fresh wool, and it changes suddenly or gradually in diameter, and suddenly widens again with a little swelling, and then thins off again; the cross markings or scales are also almost obliterated. When liquor potassæ is applied the shoddy wool is attacked much more quickly than fresh wool.

The wool from the Angora goat is known as mohair, and is largely used in the making of plushes, velvets, astrachans, and other fancy fabrics. Alpaca comes from the Peruvian sheep, a kind of llama. It is a very fine silky wool and greatly used for shawls and umbrellas. Cashmere is a specially soft and fine wool from the Thibet goat; it is very expensive and difficult to get. Camel's hair is really a fine wool; it is now chiefly met with in the underclothing of Jaeger. Wool is largely used for the making of flannel, cloth, blankets, worsteds, and knitted goods. Felt is really wool made up without either weaving or spinning, the whole holding together simply by the cohesion of the serrated fibres.

Furs.—These are the skins of certain animals from cold countries, which have, in addition to their long "overhair," a dense hairy covering called fur. The chief are bear, seal, chinchilla, ermine, and Russian sable or marten. Fur is often used for making felt; hat felts are chiefly made by compression under heat and moisture of the fur from horses and rabbits. The coarser felts used for carpets are made from cow-hair.

Leather.—The skins of animals, if appropriately prepared by tanning. tawing, or shammoying, are rendered tough, yet soft and fit for use by man as clothing. The chief skins so used are those of the ox, sheep, horse, and goat. *Tanning* is the steeping of a skin in an infusion of oak bark or other substances rich in tannic acid. By this process, insoluble tannates of the gelatin and albumin of the hides are formed. To be properly carried out, tanning takes nearly a year. Recent disclosures suggest that much American leather is tanned imperfectly and largely weighted with glucose, barium salts and magnesium; the result of this treatment is a porous and non-water-resisting leather.* *Tawing* is the same process as tanning, except that mineral astringents, such as alum and bichromate of potash, are used in place of the vegetable product, tannic acid. Tawing is more rapid, but yields an inferior and harsher leather than tanning. *Shammoying* is the impregnating of a skin with fish oil; it is chiefly applied to light skins, and is the process by which chamois leather is prepared.

Feathers are not much used for actual clothing, but rather as ornaments. Their employment is still considerable for stuffing pillows and beds.

* Evans: "On the Manufacture of Sole Leather," *Journ. Royal San. Institute*, 1906, vol. xxvii. p. 568.

These latter, if not made too soft and luxurious, are quite as healthy as any other bed.

Silk.—This is the strong fibre produced or spun by the caterpillar or larval stage of certain moths. The silk threads are formed in two small glands situated on the under part of the body and opening by a duct on the lower lip; the silk serves as a protecting sheath or covering, called a cocoon, for the silkworm when about to assume the chrysalis stage. The silk thread so ejected by each worm and wound into a cocoon measures some 4000 yards in length and consists of two fine filaments, one from each gland, laid side by side and agglutinated together into a single thread or fibre. The best silk is produced by the larva of the moth called *Bombyx mori*, or Chinese silk-moth. Other kinds of silk are spun from other silkworms closely allied to the *B. mori*. There are the *B. textor* and *B. fortunatus* common in Bengal; the *B. crœsi* found in Madras; the *B. arracanensis*, met with in Burmah; and the *B. sinensis*, belonging to China. All these are mulberry feeders. The caterpillar of another moth called *Antherœa pernyi*, found in Mongolia, and which feeds on oak leaves, spins the kind of silk known as tussur silk. The *A. mylitta* is another variety of the tussur silk-moth, common in India. It feeds on bher-trees and other shrubs. Similar moths are found in Assam and Japan. The silk fibre (Fig. 50) consists of a central core or fibre, covered with a waxy and albuminous colouring-matter. Microscopically, silk fibres are structureless and glass-like, usually measuring some $\frac{1}{2000}$th inch thick, and without surface markings or scales. Silk is insoluble in water, alcohol, and ether, but dissolves in very strong alkalies, mineral acids, and acetic acid. It is readily distinguished from wool or other animal fibre by the action of an alkaline solution of lead oxide, which, owing to the presence of sulphur in wool, darkens it, but does not affect silk. Silk is distinguishable from the vegetable fibres by being stained yellow by picric acid. The average cocoon yields some 500 yards of workable silk, which in its manufactured form is either reeled or spun silk—this latter being prepared by carding or spinning from the waste and spoiled cocoons. During its manufacture into fabrics, silk fibre is largely altered, expanded, weighted, and dyed by various re-agents, notably salts of tin and iron, which render the term "silk," as applied to actual articles of clothing, a more or less conventional expression. Silk is mainly used in the manufacture of satins, silks, plushes, velvets, ribbons, crape, and in a few woollen goods to give them lustre. Silk is very absorbent of moisture, and is a non-conductor of electricity.

Fig. 50.—Silk Fibres.

Cotton is the downy hair of the seeds of plants belonging to the family Gossypium, of the order Malvaceæ. The cotton fibres consist mainly of cellulose, and vary from ½ to 1 inch in length. The fibres are freed from the seeds by machinery, and after being cleaned and spun into yarn, are woven into fabrics, which, after being bleached, are "finished" for the market. This finishing process usually involves mangling, starching and damping, and often includes filling up the interstices between the fibres with compounds to give weight and a false appearance. Cotton is largely made up into sheeting, calico, towelling, jean, fustian, velveteen, flannelette, and paper. When mixed with wool, it constitutes the merino of vests, socks, and many fancy materials; it is also mixed with silk or the cheaper kinds of silken goods.

Microscopically, cotton is a diaphanous substance formed of fibres about $\frac{1}{1000}$th of an inch in diameter, flattened in shape, and riband-like, with an interior canal which is often obliterated, or may contain some extractive matters, borders a little thickened, the fibres twisted at intervals (about 600 times in an inch) (Fig. 51). It has been stated that the fresh cotton fibre is a cylindrical hair with thin walls, which collapse and twist as it becomes dry. Iodine stains them brown; iodine and sulphuric acid (in very small quantities) give a blue or violet-blue; nitric acid does not destroy them, but unrolls the twist.

As an Article of Dress.—The fibre of cotton is exceedingly hard, it wears well, does not shrink in washing, is very non-absorbent of water (either into its substance or between the fibres), and conducts heat rather less rapidly than linen, but much more rapidly than wool. It is very absorbent of odours. The advantages of cotton are cheapness and durability; its hard non-absorbing fibre places it far below wool as a warm water-absorbing clothing. In the choice of cotton fabrics there is not much to be said; smoothness, evenness of texture and equality of spinning are the chief points.

In cotton shirting and calico, cotton is alone used; in merino and other fabrics it is used with wool, in the proportion of 20 to 50 per cent. of wool, the threads being twisted together to form the yarn.

Fig. 51.—Cotton Fibres.

Cellular cloth is made principally from cotton. The fibres are so woven as to leave large cellular interspaces in the fabric, and the air contained therein renders it an excellent non-conductor; its warmth depends on its porous character. It is said to be very durable.

Ramie is a material which has come into considerable use, of late years, for the making of underclothing, such as vests and shirts. It is yielded by one or more species of *Bœhmeria*, more particularly by *B. nivea*, of the order Urticaceæ, growing as a shrubby plant with foliage and inflorescence like the common nettle, but destitute of stinging hairs. It is cultivated mainly in Malay, China, Japan and some parts of India. Many difficulties have been encountered in the working of this fibre, as it is difficult of extraction owing to the large amount of adhesive matter in which it is embedded. Ramie fibre is somewhat hard and inelastic, and does not readily work up into closely spun fabrics; for this reason it is excellently well adapted for the weaving of so-called cellular cloth. The fibre is, moreover, a very bad conductor of heat and more or less unshrinkable. We have worn vests made of this material and found it remarkably durable and wonderfully comfortable, giving the wearer a curious sensation of being both cool and warm at the same time. So impressed are we with the advantages attaching to this fibre that we predict a considerable future for material made of it.

Flax is a fibre obtained from the stalks of a plant called the *Linum usitatissimum*, which grows to a large extent in Russia and Ireland. The seeds are the familiar linseed, from which linseed meal, oil, and cake are prepared. The stalks, after being allowed to ferment or rot on the ground in the damp, are beaten and combed until something like 6 per cent. of saleable flax fibre is obtained from the plant. The flax or linen fibres (Fig. 52),

when seen under the microscope, are marked by transverse striæ at regular intervals; they are not flat like cotton, but more like silk, only they show a fibrous and jointed structure which is not met with in silk. Flax is much more expensive than cotton, and is used chiefly for the manufacture of linen, cambric, and lawn. Linen resembles cotton in being a good conductor of heat and a bad absorbent of moisture. It is in many respects inferior to cotton for underclothing, but from its smoothness and lustre is unequalled as a material for collars, cuffs, and shirt fronts. Weight for weight, flax fibre is stronger than cotton, in the ratio for single yarn of 3 to 1·8, for double yarn as 3 to 2·25, and for cloth as 3 to 2·1.

Jute is a brittle and very hygroscopic fibre obtained from the *Corchorus capsularis*, a plant growing chiefly in Bengal. Jute is not much used for clothing except as an adulteration of silk and in the making of false hair; it is chiefly employed for coarse fabrics, such as mats, cheap carpets, sacking, curtains, and table-covers. It is used also as a backing for floorcloths. The fibres are brittle and very hygroscopic; often hollow, thickened, and marked by constrictions; sometimes an air-bubble may be seen in the fibre.

Hemp is another fibre not much used in European countries for clothing. It is a coarse fibre, prepared from the stem of the *Cannabis sativa*, a plant growing in Europe, Asia, and America. It is prepared like flax and jute, and chiefly used for rope, yarn, canvas packing and sail-cloth. The Indian plant yields a narcotic drug, while hemp-seed is a popular food for birds.

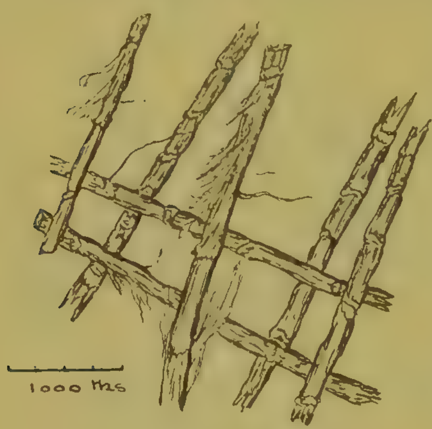


FIG. 52.—LINEN FIBRES.

The hemp fibre is something like flax, but much coarser, and at the knots it separates often into a number of smaller fibres.

Coir is a coarse, tough, harsh, yet light fibre obtained from the husk of the cocoa-nut. It is rarely used for clothing, but largely so for making mats, brushes, and ropes.

India-rubber enters largely in the present day into the constitution of our clothing, chiefly because it is elastic and impermeable to water. Under the name of caoutchouc, it is the milky juice of several plants growing in Africa, Asia, and South America. Caoutchouc is a somewhat complex body, dissolving in chloroform, ether, petroleum, benzene, and carbon disulphide. Freezing impairs its elasticity, while great heat softens and melts it. Fats also destroy it. When steeped in melted sulphur at 140° C., caoutchouc becomes vulcanised. Macintosh cloth is merely a cotton or silk fabric covered, layer by layer, with a solution or paste of caoutchouc. Gutta-percha is, like india-rubber, the juice of certain trees; but these grow only in the Malay peninsula. Excepting as boot soles, gutta-percha is little used in clothing.

PRINCIPLES OF SELECTION AND CONSTRUCTION OF CLOTHING.

Warmth and coolness, or the power of maintaining the body heat at its normal height, being the most important property of all dress materials, it follows that our choice of clothing will depend largely upon this feature. How far a given clothing will give warmth depends upon its material, its

texture, number of layers, and its colour. Owing to fabrics conducting heat in the following order from highest to lowest, namely, linen, cotton, silk, feathers, fur, and wool, it follows that wool, fur, and feathers are the warmest materials, then silk and cotton; while linen is the coolest. The more readily a material conducts heat, of course, the cooler it feels. This heat-conducting property is mainly proportionate as to how close it is woven, and as to how little air it contains. On this account, all soft, furry fabrics, no matter whether of wool or cotton, always feel warmer than the closely woven, smooth-surfaced silks and linens. In the same way, the more layers of clothing there are, the more layers of air there are retained between them. The influence of colour is dependent upon the heat-absorbing powers of that colour. White absorbs heat the least, and is consequently the coolest; then come yellow, red, green, blue, and black. It is obvious this effect of colour can only be of influence when outside, and that the popular idea that red flannel, when worn next the skin, or as part of an under-garment, is warmer than white is imaginary. As a rule, it is a mistake to wear coloured clothing next the skin, as not unfrequently the dyes are irritative, and, coming off, give rise to skin diseases.

In determining the selection of a material for clothing, its hygroscopic or absorbent power for water is of the first importance. The hygroscopic qualities of wool are undoubtedly far greater than those of other fibres, especially the vegetable, but these latter certainly absorb more water than is generally realised. The variations in this respect, between different materials, is largely due to the manner in which the manufactured article is woven. There can be no doubt that, as a general rule, woollen goods will absorb far more water than cotton, but if we compare the absorbent power of a closely woven woollen fabric with that of a loosely woven cotton, such as bath towelling, there is very little difference between them; in fact, if anything, the margin is in favour of the cotton material. Flannel absorbs moisture readily, and by virtue of its high hygroscopic power, evaporation from its surface is slow. It is for this reason that flannel constitutes the best material for garments for those perspiring freely; the evaporation being slow and gradual causes the chilling of the body, when exercise ceases, to be comparatively slight. On the other hand, if a man perspires freely in an ordinary close-woven cotton or linen garment, this rapidly becomes wet through, adheres to the skin, evaporation quickly proceeds, leading to great surface chilling and loss of heat. The more recent method of weaving cotton materials more loosely has undoubtedly reduced the general defects of cotton clothing in this respect.

For this country, flannel and woollen goods are the safest materials to wear; but if cotton or linen be worn, it must be so woven as to give both thickness and porosity to the fabric. In the tropics, wool is too heavy a material, linen or cotton shirting being more generally suitable. The Chinese habit of wearing a net next to the skin in hot weather, with a thin silken garment over it, is a good one; the net, without increasing the heat, prevents the perspiration soaking into the upper garment, and the latter from fitting too closely to the skin.

Reference, in this place, may not be inappropriate to the various forms of waterproof clothing now worn. Except under extreme circumstances of rain, the use of india-rubber garments is to be absolutely condemned; being impermeable, evaporation is minimised, with the result that the body quickly breaks out into perspiration, accompanied by more or less discomfort. On the other hand, impregnated woollen and other materials, waterproof but at the same time porous, have probably a great future. In examining such

materials, it is essential to note whether they are permeable to air or not. This can very readily be done by stretching the fabric over a pipe or tube and observing whether air blown down the tube can pass through the tissue sufficiently to effect a candle flame.

A well-prepared waterproof material will permit of a candle being extinguished, when blown through a 1-inch pipe, at a distance of 6 inches. Poore, quoting from Cooley, gives the following methods for preparing a waterproof cloth :—

1. Moisten the cloth on the wrong side with a weak solution of isinglass, and, when dry, further moisten with an infusion of nut-galls.

2. Moisten the cloth on the wrong side with a solution of soap, and, when dry, with a solution of alum.

3. Thoroughly rub the wrong side of the cloth with pure beeswax, free from grease, until it presents an even grey appearance ; a hot iron is then to be passed over it, and the cloth being brushed whilst warm, the process is complete.

While affording warmth, protection from wind, wet and injury, clothing should always be so made as not in any way to impede natural movements, nor unduly constrict any part of the body, nor be needlessly heavy, and also not afford unnatural support. The more we analyse the common forms of clothing, the more we see that their main faults are in the direction of impediment, constriction, and weight. This is particularly emphasised in the case of long and close-fitting skirts, tight sleeves, stays, garters, bands round the waist and neck, ill-fitting gloves, hats, and boots.

Many of these defects and faults would be obviated if people would remember that (1) no article of clothing should be either so tight as to interfere with the circulation, or so shaped as to change the natural outline of any part of the body ; (2) no garment should contain more material than is actually necessary ; (3) all garments requiring suspension should be suspended directly or indirectly from the shoulders or hips.

Probably no article of attire is more faulty than the boot. A properly made boot should fit the foot accurately ; the great toe should be in a straight line with the inside of the foot ; the shape of the sole of the boot should be taken by drawing a pencil round the outline of the foot when the weight of the body is resting on the foot, as in standing, so that the sole may be big enough to support the fully expanded foot ; the material should be of soft and flexible leather ; even when new, the wearer ought to be able to move all the toes with freedom in the boot ; the heel should be broad and low. The stocking or sock should, whenever possible, be of a woollen material or a mixed material in which wool predominates. If no sock be worn, the boot needs to be high and close-fitting round the ankle, so as to prevent dust and stones getting into the boot. The sole of a boot should be wider than the foot, and if the boot is meant for hard wear, the excess of breadth in the sole should be considerable, so as to serve as a protection against loose stones.

CHAPTER VIII

EXERCISE

A PERFECT state of health implies that every organ has its due share of exercise. If this is deficient, nutrition suffers, the organ lessens in size, and evidently more or less degenerates. If it be excessive, nutrition, at first apparently vigorous, becomes at last abnormal, and in many cases a degeneration occurs which is as complete as that which follows the disuse of an organ. Every organ has its special stimulus which excites its action, and if this stimulus is perfectly normal as to quality and quantity, perfect health is necessarily the result.

But the term exercise is usually employed in a narrower sense, and expresses merely the action of the voluntary muscles. This action, though not absolutely essential to the exercise of other organs, is yet highly important, and, indeed, in the long-run, is really necessary; the heart especially is evidently affected by the action of the voluntary muscles, and this may be said of all organs, with the exception, perhaps, of the brain. Not only the circulation of the blood, but its formation and its destruction, are profoundly influenced by the movement of the voluntary muscles. Without this muscular movement health must inevitably be lost, and it becomes therefore important to determine the effects of exercise, and the amount which should be taken.

THE EFFECTS OF EXERCISE.

On the Lungs. Elimination of Carbon.—The most important effect of muscular exercise is produced on the lungs. The pulmonary circulation is greatly hurried, and the quantity of air inspired, and of carbon dioxide expired, is marvellously increased.

It seems certain that the great formation of carbon dioxide takes place in the muscles; it is rapidly carried off from them, and if it were not so, it seems highly probable that their strong action would become impossible. At any rate, if the pulmonary circulation and the elimination of carbon dioxide are in any way impeded, the power of continuing the exertion rapidly lessens. The watery vapour exhaled from the lungs is also largely increased during exertion. Muscular exercise is then clearly necessary for a sufficient elimination of carbon from the body, and it is plain that, in a state of prolonged rest, either the carboniferous food must be lessened or carbon will accumulate. Excessive and badly arranged exertion may lead to congestion of the lungs, and even hæmoptysis. This sequence of events arises often less from any excess of exertion than from faulty respiration; for this reason, the promotion of correct respiratory habits, involving nasal breathing and full expansion of the lungs, is an essential safeguard against pulmonary affections.

Certain rules flow from these facts. During exercise the action of the lungs must be perfectly free; not the least impediment must be offered to

the freest play of the chest and the action of the respiratory muscles. The dress and accoutrements of the soldier should be planned in reference to this fact, as there is no man who is called on to make, at certain times, greater exertion. And yet, till a very recent date, the modern armies of Europe were dressed and accoutred in a fashion which took from the soldier, in a great degree, that power of exertion for which, and for which alone, he is selected and trained. The action of the lungs should be watched when men are being trained for exertion; as soon as the respirations become laborious, and especially if there be sighing, the lungs are becoming too congested, and rest is necessary.

A second point is that the great increase of carbon excreted demands an increase of carbon to be given in the food. There seems a general accordance among physiologists that this is best given in the form of fat, or sugar, and this is confirmed by the instinctive appetite of a man taking exertion, and not restrained in the choice of food.

A third rule is that, as spirits lessen the excretion of pulmonary carbon dioxide, they are hurtful during exercise; and it is perhaps for this reason, as well as from their deadening action on the nerves of volition, that those who take spirits are incapable of great exertion. This is now well understood by trainers, who allow no spirits, and but little wine or beer. It is a curious fact that if men undergoing exertion take spirits, they take less fat. Oxidation of fat is interfered with, and therefore less fat is required. Water alone is the best liquid to train on.

A fourth rule is that, as the excretion of carbon dioxide is so much increased, a much larger amount of pure air is necessary; and in every covered building (as gymnasia, riding-schools, &c.) where exercise is taken, the ventilation must be carried to the greatest possible extent, so soon does the air become vitiated.

On the Circulation.—The action of the heart rapidly increases in force and frequency, and the flow of blood through all parts of the body, including the heart itself, is augmented. The amount of increase is usually from ten to thirty beats, but occasionally more. After exercise, the heart's action falls below its normal amount; and if the exercise has been exceedingly prolonged and severe, may fall as low as fifty or forty per minute, and become intermittent. During exertion, when the heart is not oppressed, its beats, though rapid and forcible, are regular and equable; but when it becomes embarrassed, the pulse becomes very quick, small, and then unequal, and at last irregular. When men have gone through much exertion, and then are called upon to make a sudden effort, the pulse may become very small and quick, but still retain its equability. There seems no harm in this, but such exertion cannot be long continued.

The ascent of heights greatly tries a fatigued heart. The accommodation of the heart to great exertion is probably connected with the easy flow of blood through its own structure. Certain forms of chronic disease of the heart have been treated by the "mountain cure," introduced by Oertel; but very great caution is required in carrying out this treatment, and high elevations are contra-indicated in these affections.

Excessive exercise leads to affection of the heart—rupture (in some few cases), palpitation, hypertrophy in many cases, and more rarely valvular disease. These may be avoided by careful training, and a due proportion of rest. Injuries to vessels may also result from too sudden or prolonged exertion. The blood pressure falls almost invariably after and during exercise. Deficient exercise leads to weakening of the heart's action, and probably to dilatation and fatty degeneration.

In commencing an unaccustomed exercise, the heart must be closely watched; excessive rapidity (120–140), inequality, and irregularity will point out that rest, followed by gradual exercise, is necessary, in order that the heart may be accustomed to the work.

On the Skin.—The skin becomes red from turgescence of the vessels, and perspiration is increased; water, chloride of sodium, and acids pass off in great abundance. Some nitrogen passes off in a soluble form as urea, but the amount is extremely small; it is increased on exertion with the increased perspiration. No gaseous nitrogen is given off in healthy men from the skin.

The amount of fluid passing off from the skin is not certain, but is very great. Speck's * experiments show that it is at least doubled under ordinary conditions of exercise. Pettenkofer and Voit's experiments show even a larger increase. The usual ratio of the urine to the lung and skin excreta is reversed. Instead of being as 1 to 0·5 or 0·8 it becomes as 1 to 1·7 or 2, or even 2·5. This evaporation reduces and regulates the heat of the body, which would otherwise soon become excessive; so that the body temperature rises little above the ordinary temperature. No amount of external cold seems to be able to check the passage of fluid, though it may partly diminish the rapidity of evaporation. If anything checks evaporation, the body-heat increases, and soon languor comes on and exertion becomes difficult.

During exertion there is little danger of chill under any circumstances; but when exertion is over, there is then great danger, because the heat of the body rapidly declines, and falls below the natural amount, and yet evaporation from the skin, which still more reduces the heat, continues.

The rules to be drawn from these facts are:—that the skin should be kept extremely clean; during the period of exertion it may be thinly clothed, but immediately afterwards, or in the intervals of exertion, it should be covered sufficiently well to prevent the least feeling of coolness of the surface. Flannel is best for this purpose.

On the Nervous System.—The effect of exercise on the mind is not clear. It has been supposed that the intellect is less active in men who take excessive exercise, owing to the greater expenditure of nervous energy in that direction. But there is no doubt that great bodily exercise is quite consistent with extreme mental activity; and, indeed, considering that perfect nutrition is not possible except with bodily activity, we should infer that sufficient exercise would be necessary for the perfect performance of mental work. Doubtless, exercise may be pushed to such an extreme as to leave no time for mental cultivation; and this is perhaps the explanation of the proverbial stupidity of the athlete. Deficient exercise causes a heightened sensitiveness of the nervous system, as evidenced by excitability, and a greater susceptibility to the action of external agencies.

On the Kidneys.—The water of the urine and the chloride of sodium often lessen in consequence of the increased losses from the skin. The urea is not much changed, but the uric acid, and also apparently the pigment, increase after great exertion. The phosphoric acid is not augmented unless the exertion is excessive; while the sulphuric acid and free carbonic acid are commonly increased. The exact amount of the bases has not been determined, but a greater excess of soda and potash is eliminated than of lime or magnesia; nothing certain is known as to hippuric acid, sugar, or other substances. In the careful observations made by Pavy on Weston, the pedestrian, it was found that all the constituents of the urine were

* Speck: *Archiv des Vereins. f. Wiss. Heilkunde*, Bd. vi. p. 285.

increased, except the chlorine and the soda, which were notably diminished, especially the chlorine; the magnesia was also lessened, but in a much smaller degree. In these experiments, however, the diet was not uniform, and the exercise was excessive.

On the Bowels.—The general effect of exercise is to lessen the amount of excreta passed, probably from a reduced amount of water entering the intestines. The experiments of Parkes and North indicate that the amount of nitrogen voided by the bowels is not much altered.

On the Elimination of Nitrogen.—A great number of experiments have been made on the amount of nitrogen passing off by the kidneys during exercise, notably by Parkes,* Voit,† Pettenkofer, Ranke, Smith, Haughton, and others. The amount of urea has been usually determined, and the nitrogen calculated from this. The observations have been commonly made by determining the nitrogenous excretion in twenty-four hours with and without exercise; but in some the period during which work was actually performed was compared with previous and subsequent equal rest periods. Some experiments were performed on men who took no nitrogen as food; others were on men on a constant diet, so that the variation produced by the altering ingress of nitrogen was avoided as far as possible.

In this place it is impossible to give an account of these long researches, and therefore only a short summary can be given. (1) When a period of exercise is compared after an interval with one of rest (the diet being without nitrogen or with uniform nitrogen), the elimination of nitrogen by the kidneys is decidedly not increased in the exercise period. The experiments on this point are now so numerous that it may be stated without doubt. It is possible that the elimination may even be less during the exercise than during the rest period. (2) When a day of rest is compared with a day of work (*i.e.*, a day with some hours of work and some hours of rest), the amount of nitrogen is almost or quite the same on the two days; if anything there is a slight increase in the nitrogen on the rest-day. In a day of part exercise and part rest, it is quite possible that there may be compensatory action, one part balancing the other, so as to leave the total excretion little changed. (3) When a period of great exercise is immediately followed by an equal period of rest, the nitrogenous elimination is increased in the latter. Meissner's observations show that this is in part owing to increased discharge of kreatin and kreatinin; Parkes' observations also show an increase of non-ureal nitrogen. But the urea is also slightly increased in this period. (4) When two days of complete rest are immediately followed by days of common exercise, the nitrogenous elimination diminishes during the first day of exercise (Parkes).

North's experiments in the main confirm the observations of Parkes, but he shows that the effects of heavy labour are more immediate and severe than was shown by those observations.‡ North found that deprivation, or an excessive output of nitrogen, was followed by retention and absorption. There is also a tendency to the storage of nitrogen in the system under ordinary conditions, which shows a tendency to economy in the body. From this we might deduce the value of a good diet as providing a reserve against a period of deprivation or excessive work. A similar tendency to the storage of nitrogen was shown in the case of Weston, whose ingesta or egesta were examined by Wynter-Blyth.

* Parkes: *Proc. Roy. Soc. Lond.*, Nos. 89 and 94, 1867; *also* Nos. 127 and 136, 1868.
† Voit: *Zeitsch. f. Biol.*, ii. and iii.; *also* in Ranke's *Physiol. des Menschen*, p. 551.
‡ North: "On the Elimination of Nitrogen during Exercise," *Proc. Roy. Soc. Lond.* xxxvi. p. 11, and xxxix. p. 46.
§§ Wynter-Blyth: *Proc. Roy. Soc. Lond.*, 1884, xxxvii. p. 46.

On the whole, if the facts have been stated correctly, the effect of exercise is certainly to increase the elimination of nitrogen by the kidneys, but within narrow limits, and the time of increase is in the period of rest succeeding the exercise; whereas during the exercise period the evidence, though not certain, points rather to a lessening of the elimination of nitrogen.

It would appear from these facts that well-fed persons taking exercise would require a little more nitrogen in the food, and it is certain, as a matter of experience, that persons undergoing laborious work do take more nitrogenous food. This is the case also with animals. The possible reason of this will appear presently.

On the Temperature of the Body.—As already stated, the temperature of the body, as long as the skin acts, rises little. A number of observations made on soldiers, whether carrying loads or not, shows that the temperature rises some two or three degrees after severe exercise; this rise, however, soon disappears and the temperature reverts to the normal.

The Exhaustion of Muscles.—There seems little doubt but that this is owing chiefly to two causes, namely, loss of substance necessary to contraction, and accumulation of the so-called fatigue products. Some work of Lee is interesting on this matter.* Phloridzin was administered to cats for a length of time, the result being that the animals became muscularly very weak, while at the same time, as is well known, a severe glycosuria was established. Single muscles were removed from the body, these gave only a few contractions, and graphic records of these revealed a condition of pronounced fatigue. This was not due to any direct toxic effect of the substance upon the muscles, but rather that the drug robbed the body of carbo-hydrate material both in the loose form as well as that combined in the protein molecule. Hence we may assume that normal muscular fatigue is associated with loss of carbo-hydrate from the muscles; this view is strengthened by the fact that when prolonged phloridzin poisoning is followed by the administration of dextrose, the contractibility of the muscles is restored rapidly. This coincides with Mosso and V. Harley's observations on the notable value of sugar in lessening muscular fatigue. Various considerations justify the conclusion that, in normally induced fatigue, there is a first stage of simple fatigue caused by the accumulation of fatigue products, followed by a stage of exhaustion due chiefly to the loss of carbo-hydrate substances.

General Effect of Exercise on the Body.—As judged by the preceding facts, the main effect of exercise is to increase oxidation of carbon and perhaps also of hydrogen. Exercise also eliminates water from the body, and this action continues for some considerable time, so that after exercise the body, especially the blood, is poorer in water. It increases the rapidity of circulation everywhere, as well as the pressure on the vessels, and therefore it causes in all organs a more rapid outflow of plasma and absorption—in other words, a quicker renewal. In this way also it removes the products of their action, which accumulate in organs, and restores the power of action to the various parts of the body. It increases the outflow of warmth from the body by increasing perspiration. It therefore strengthens all parts. It must be combined with increased supply both of nitrogen and carbon (the latter possibly in the form of sugar), otherwise the absorption of oxygen, the molecular changes in the nitrogenous tissues, and the elimination of carbon, will be checked. There must be also an increased supply of salts, certainly of chloride of sodium; probably of potassium phosphate and chloride. There must be proper intervals of rest, or the store of oxygen, and

* Lee: "Proc. Internat. Congress of Physiologists," *Lancet*, November 9, 1901, p. 1289.

of the material in the muscles which is to be metamorphosed during contraction, cannot take place. Another effect of exercise is that it has some influence in lowering the opsonic index even in healthy persons.* This has been established in respect of both the tubercle and the enteric bacilli. In the case of the latter, may not the lessened resisting power of the body, as shown by a fall in the opsonic index, explain the apparent vulnerability of young soldiers to enteric infection following excessive exertion and fatigue? The evidence on this point is, at present, somewhat meagre, but the few observed facts are extremely suggestive.

AMOUNT OF EXERCISE WHICH SHOULD BE TAKEN.

It would be extremely important to determine, if possible, the exact amount of exercise which a healthy adult, man or woman, should take. Every one knows that great errors are committed, chiefly on the side of defective exercise. It is not, however, easy to fix the amount even for an average man, much less to give any rule which shall apply to all the divers conditions of health and strength. But it is certain that muscular work is not only a necessity for health of body, but for mind also; at least it appears that diminution in the size of the body from deficient muscular work seems to lead in two to three generations to degenerate mental formation.

The hardest day's work of twelve hours noted by Parkes was in the case of a workman in a copper rolling-mill. It is stated that this man occasionally raised a weight of 90 pounds to a height of 18 inches 12,000 times a day. Supposing this to be correct, he would raise 723 tons 1 foot high. But this much exceeds the usual amount. The same man's ordinary day's work, which he considered extremely hard, was raising a weight of 124 lb. 16 inches 5000 or 6000 times in a day. Adopting the larger number, this would make his work equivalent to 443 tons lifted a foot; and this was a hard day's work for a powerful man. Some of the puddlers in the iron country, and the glass-blowers, probably work harder than this; but there are no calculations recorded. From the statement of a pedlar, his ordinary day's work was to carry 28 lb. 20 miles daily. The weight is balanced over the shoulder—14 lb. behind and 14 lb. in front. Assuming the man to weigh 160 lb., the work is equal to 443 tons lifted 1 foot. It would, therefore, seem certain that an amount of work equal to 500 tons lifted a foot is an extremely hard day's work, which perhaps few men could continue to do. Four hundred tons lifted a foot is a hard day's work, and 300 tons lifted a foot is an average day's work for a healthy, strong adult. The work usually calculated for a horse in the army is 3000 foot-tons, and $\frac{1}{7}$th of this is just 430, nearly the work of the pedlar above mentioned.

By his philosophical studies and writings on this subject, Haughton has shown that walking on a level surface at the rate of about 3 miles an hour is equivalent to raising $\frac{1}{20}$th part of the weight of the body through the distance walked; an easy calculation changes this into the weight raised 1 foot. When ascending a height, a man of course raises his whole weight through the height ascended.

The formula is $\frac{(W+W') \times D}{2240} \times C =$ foot-tons: where W = weight of the person, and W′ the weight carried, both in pounds; D the distance, in feet; and C the co-efficient of traction; 2240 is the number of pounds in a ton;

* Ellett: "On the Effect of Bodily Exertion on the Opsonic Index," *Brit. Med. Journal*, July 21, 1906, p. 131.

the distance walked in miles must be multiplied by 5280 to bring it to feet. The result is the number of tons raised one foot. Haughton gave the coefficient for a velocity of 1 mile an hour to be $\frac{1}{38}$th, for 2 miles an hour $\frac{1}{27}$th, for 3 miles an hour $\frac{1}{20}$th, for 4 miles an hour $\frac{1}{16}$th, and for 5 miles an hour $\frac{1}{14}$th.*

Using the above formula, and assuming a man to weigh 160 lb. with his clothes and to carry 60 lb. in addition, then a walk of 10 miles at a rate of 3 miles an hour would mean, as external work done, some 260 tons lifted 1 foot, or 189 Calories.

In the case of a soldier, if he were allowed to march easily, and if the weights were not oppressively arranged, he ought to do easily 12 miles daily for a long time, provided he was allowed a periodical rest. But he could not for many days, without great fatigue, march 20 miles a day with a 60 lb. load, unless he were in good condition and well fed. If a greater amount still is demanded from him, he must have long subsequent rest. But all the long marches by our own or other armies have been made by men carrying only small loads, such as arms and a portion of ammunition. Under these conditions great distances have been traversed by men in good training.

V. Harley's † observations indicate that the periods of digestion, as well as the kinds of food taken, have a marked influence on voluntary muscular energy, and that, irrespective of the influence of food, there is a periodical diurnal rise and fall of power for the performance of muscular work. He shows that more work can be done after than before midday; the minimum being about 9 A.M., and the maximum about 3 P.M. Sugar taken early in the evening is capable of obliterating the diurnal fall in muscular power that occurs at this time, and increases the resistance to fatigue. Harley states that the effect of sugar is so great that the amount of work performed on a diet of sugar alone is almost equal to that obtained on a full diet; fatigue, however, setting in sooner. Moderate smoking, although it may have a slight influence in diminishing the power of doing voluntary muscular work, neither stops the morning rise, nor, when done early in the evening, hinders the evening fall. These conclusions are very interesting, but having been made exclusively upon a small group of muscles of the forearm under very artificial conditions, it is doubtful whether they can be accepted entirely for the whole body.

What is known as "training" is a systematic effort to increase breathing power; to make the muscular action more vigorous and enduring, and to lessen the amount of fat. This is obtained by a very careful diet, containing little or no alcohol; by regular and systematic exercise; and by increasing the action of the eliminating organs, especially of the skin. What the trainer thus accomplishes is in essence the following:—a concordant action is established between the heart and blood-vessels, so that the strong action of the heart, during exercise, is met by a more perfect dilatation of the vessels, and there is no blockage of the flow of blood; in the lungs, the blood not only passes more freely, but the amount of oxygen is increased; this gradual improvement in breathing power is well seen when horses are watched during training. The reciprocal action of heart and blood-vessels is the most important point in training; the nutrition of nerves and muscular fibres improves from the constant action and the abundant supply of food; the tissue changes are more active, and elimination, especially of carbon, increases. A higher condition of health ensues, and, if not carried to excess, "training" is simply another word for healthy and vigorous living.

* Haughton: *The Principles of Animal Mechanics*, Lond. 1873.

† V. Harley: *Journ. of Physiology*, vol. xvi., Nos. 1 and 2, 1894, p. 97.

CHAPTER IX

SOIL

Though the term soil may, in a general sense, be taken to express all the portion of the earth's crust which by any property or condition can affect health, it is usual and convenient to divide all soils into an upper or surface soil and a deeper or subsoil layer. While the former or surface soil consists in the main of the products of the decay of large quantities of both animal and vegetable matter, constituting mould or "humus," the latter, strictly speaking, results entirely from the breaking up of the underlying primitive rocks, under the influence of water, gases and other agencies, and constitutes thereby an intermediate stage between the subjacent rock formation and the upper layers of true soil or mould. The relative thicknesses of these two layers constantly varies, for while the surface soil may be measured often only in inches or a few feet, the subsoil may extend some hundreds of feet in depth. The expression "rock" is here used in its geological sense, as meaning any hard or soft material which goes to form the solid earth, and includes clays, loose sands, and gravels.

Since the chief origin of the subsoil layers of the ground is from the gradual disintegration of rocks, the nature and composition of a soil in any given place will greatly vary, according to the geological history of the locality. Hence, from the nature of the soil, we can infer what is the quality of the rock that lies beneath it, or knowing what is the underlying rock, we may fairly correctly form an opinion as to the character of the overlying soil. Thus, sandstones, when disintegrated or denuded, will produce sandy soil, and a clay, a clayey soil, or if the two kinds of rock be together, they will produce a loam or sandy clay; the resulting soils being also more or less mixed with the remains of vegetable and animal matter. Owing, however, to the action of rain and other forces constantly moving matters to a greater or less distance from their source, the soils of various localities do not necessarily and strictly correspond to the rocks beneath them, but may result in such instances from a clay soil overlying a sandstone, or a highly fertile soil being found to rest upon a substratum of rock which, from its known composition, must, on disintegration, obviously produce a poor one. Similarly, the continual advance of sand over a country, under the action of the prevalent wind, has utterly ruined many fertile tracts, as, for example, the sandy region known as the "Landes" along the shores of the Bay of Biscay, and the "Dunes" of Norfolk and North Wales.

THE GEOLOGICAL ORIGIN OF SOILS.

Recognising the origin of all soils from the disintegration of rocks, it is of primary importance, for a complete comprehension of the nature of soils, to have some idea as to the composition of these earlier formations. All rocks are made up of one or more minerals. Those which contain more

than one mineral are merely mechanical mixtures of them and not chemical compounds. **Minerals**, on the other hand, have, as a rule, a more or less definite chemical composition, which can be expressed by a formula; they, however, differ very greatly in composition. Some consist of only one element, others of two; in the latter case, one element is often a metal, as in *pyrites*, a compound of iron and sulphur; or *fluor*, which is a compound of calcium and fluorin. The elements constituting a mineral may, however, be both non-metals, as in the case of *silica*, which consists of silicon and oxygen. The greater number of minerals consist of at least three elements, and form salts of a very complicated nature. This is particularly the case with those salts in which a non-metallic oxide like silica has combined with two or more metallic bases. Certain elements greatly preponderate in soils; those most frequently met with are oxygen, silicon, aluminium, calcium, magnesium, sodium, and potassium.

Of the various minerals, practically only four enter largely into the formation of rocks; they are quartz, felspar, hornblende and mica. The resulting rock formations have been divided by geologists into three principal kinds according to their mode of origin, namely, the igneous, the aqueous or sedimentary, and the metamorphic.

Igneous Rocks.—These are all believed to have been derived from the original molten matter of the once fluid earth; some having solidified at a considerable depth, while others have been forced upwards and then cooled and solidified at or near the surface. These rocks contain a great number and variety of minerals; these latter being for the most part double silicates of great complexity. The minerals may be in a coarse crystalline condition as in granite, or indistinguishably mixed as in the basalts, or fused into a glass as in obsidian, or loose and open as in pumice, or stratified as in volcanic ash. These varieties of texture are mainly to be explained by the different conditions under which the rock has cooled. All the various minerals of igneous rocks are built up of silica, alumina, lime, oxide of iron, soda, potash, magnesia, and water. They exist chiefly as quartz, felspar, and mica. The first is pure silica; felspar is a silicate of aluminium and of potassium, sodium, or calcium. Unlike quartz, which is most durable, felspar is prone to break down under the influence of exposure to air and rain into clay, which is nothing more than an aluminous silicate. Mica, like quartz, is not very liable to chemical change, but, by continued friction, breaks into a fine scaly sand or dust. The other minerals of the igneous rocks are mostly silicates of calcium, magnesium, aluminium, and iron. Silica, either free or combined, being the most prominent constituent of the igneous rocks, its varying percentage is often made use of to classify them; those having above 60 per cent. being called *acidic*, and those having less, *basic*.

The more general classification of the igneous rocks is into the *Plutonic* or those coarse crystalline rocks which have cooled slowly far beneath the surface, and the *Volcanic* or the scoriaceous, glassy and compact rocks which have been cooled at or near the surface. These can further be subdivided, if necessary, into acidic and basic. Of the plutonic rocks, the chief type is granite, which forms a considerable portion of the earth's surface. The crystals of granite lie closely packed in a matrix of transparent quartz. The silica of the quartz and that existing in the felspar, mica, and other minerals of granite constitutes from 62 to 80 per cent. of the whole weight, so that it belongs to the acidic class. If hornblende is present, in addition to the ordinary constituents of a granite, it is termed syenitic granite. The basic plutonic rocks are chiefly mixtures of felspars with hornblende, augite, or mica; many of them are green in colour, and are known technically as

diabase, *gabbro*, *aphanite*, and *diorite*. A crystalline mixture of hornblende and felspar is called syenite.

Of the volcanic rocks, the chief are basalt, dolerite, trachyte, obsidian, pumice, and phonolite. The broken material emitted from volcanoes is called "ash," and when more or less solidified is called *tufa*. The half-molten rocky material from volcanoes is the *lava*. This lava when dense and columnar, as in Staffa, is *basalt;* if coarser, it is called *dolorite*. The term *trap* is given to certain dark basaltic lavas, which are found spread out in great sheets over large areas in the Deccan and Sweden.

Aqueous Rocks.—These are composed of small particles which are derived from the wearing away of other rocks and of matter which has been deposited from solution or suspension in water, or from organic materials. They are often called sedimentary rocks from their mode of formation, and are of four chief kinds, namely, the argillaceous, the arenaceous, the calcareous, and the organic.

Argillaceous rocks are the result of the sedimentary deposit of mud and clay, and consist largely of impure silicate of aluminium. The various claystone formations, such as the Lias, Oxford, Kimmeridge, Wealden, and London clays, are the products of these rocks; so are the *shales*, which are merely hardened and laminated clays.

Arenaceous rocks are those formed of sand or minute rounded grains of quartz. These grains, indifferently held together by clay, silica, iron oxides, or carbonate of lime, constitute the argillaceous, siliceous, ferruginous, and calcareous sandstones and grits. Conglomerates are rocks of this class, formed by pebbles or shingle cemented together, while a breccia rock is one composed of rough and angular fragments similarly cemented. Both the argillaceous and arenaceous rocks are essentially, in their mode of origin, sedimentary.

Calcareous rocks are those which are formed of the material which has been dissolved in water and deposited therefrom by chemical action. Of this class are the various limestones, which have been deposited from solution by loss of carbonic acid on exposure to the air. The deposition of carbonate of lime from aqueous solutions at the present time is familiar in the so-called petrifying springs, and in the growth of stalactites. Some limestones are formed of little spherical grains, like the roe of a fish; these are called *oolite*. When consisting of an admixture of carbonate of lime and carbonate of magnesia, limestones are termed *dolomites*. Another rock of this class is gypsum. Flints and chert are other instances of chemical action, by which the silica scattered through the chalk has been dissolved by percolating water, and then deposited as we now find it. By a somewhat similar process, large nodules of carbonate of lime, called *Kunkur*, are formed in beds of clay in parts of India. They contain some clay, and when ground up make a kind of cement.

Organic rocks are those aqueous rocks which consist mainly of limestones derived from the shells or other hard parts of marine organisms, and of carbonaceous beds formed of plants. Among the limestones of organic origin are the coralline and crinoidal limestones, consisting largely of the remains of corals, molluscs, and crinoids. In the same way originated the shell marls and shell sands, while chalk itself, being of marine origin, is composed mostly of the remains of Foraminifera. Of the organic rocks derived from plants, coal, peat, lignite, jet, plumbago, anthracite, and bitumen are conspicuous examples.

Metamorphic Rocks.—Any mass of rock which has been altered when *in situ*, as distinguished from that which has been worn away, broken

up and deposited elsewhere, as a sedimentary rock, is said to be metamorphic. Of these metamorphic rocks, there may be said to be two groups:—one, containing those rocks which have not been so altered as to prevent the recognition of their original condition; and the other, including those whose primitive state is quite obliterated by chemical and other changes. The first group embraces the slates, mica and marl slates, marble and quartzites; in which the original clay, limestone, and sandstone formation are respectively still discernible.

The second group comprises the true metamorphosed rocks. They are characteristic of Wales and the Highlands of Scotland, and are suggestive of the influence of subterranean heat, combined with great pressure and the presence of water, whereby they have become foliated or schistose. The most abundant rock of this class is *gneiss*, which is really a granite altered by pressure. The other schistose rocks are the various schists, such as mica-schist, hornblende-schist, talc-schist, and others produced from sandy and clay deposits, the relative amount of either substance determining the character of the schist.

Formation of Soils.—From the foregoing geological survey it is clear that the igneous and metamorphic rocks are almost entirely silicates, while the softer aqueous or sedimentary rocks consist mainly of silicates, carbonates, and oxides. Changes of temperature, largely aided by frost, have cracked and broken up these various rocks mechanically. By the influence of rain and air, carbonic acid and oxygen have entered the interstices of the rocks and acted chemically upon their constituents. The carbonic acid, dissolved in water, has assisted in the disintegration of granites and basalts, by converting their contained felspar into a soluble carbonate, which, being readily carried off, has left a residue of clay behind; so that what was originally a hard granite rock has become a disintegrated mass of clayey gravel, representing the natural soil of a granite district. Basalt suffers in the same way, breaking up into a gritty clay containing nodular masses of greyish coloured stone, as noticeable on the moors of north Yorkshire. Upon the limestones, the carbonated waters have acted in a similar manner, slowly dissolving away the carbonate of lime and leaving undissolved the clay and flints. This clay with flints constitutes the natural soil of the chalk districts, while the clay without the flints is familiar in the limestone regions. Both by means of water and air, oxygen acts upon the various substances in the rocks, converting the carbonates and silicates of iron into oxides, and contributing not a little to the varying colours of different soils. In these and other ways the external surfaces of rocks become "weathered."

Generally speaking, the acid igneous rocks decompose into clay, silica, and alkaline carbonates, thus weathering into clayey soil which contains particles of quartz, felspar, and mica, as evidenced by the loams so commonly found over granites and schistose rocks. The basic rocks resolve largely into clay and carbonates of calcium, magnesium, and iron, yielding marls or coloured clays.

The formation of surface soils, from the weathering and decomposition of rocks, is by no means a purely chemical process caused by the direct action of rain and air, but is also in large part aided by the presence and action of both animal and vegetable life. From both animals and plants there is furnished, to the soil, matter, which not only adds to its bulk, but enriches it and renders it still more suitable for plant life. This is continually being removed by rain, which either runs off or through it and, as continually, is replenished by the breaking up of the rocks below and the decaying vegetable matter above. The upper layers, in which organic

matter predominates, are carried down by rain, and the lower and more mineral portions are brought to the surface by burrowing insects, worms, moles, and rabbits. In this manner the organic and inorganic matters of the earth are constantly being intermingled and renewed, and the soil both increased and improved. To these agencies must be added the constant action of wind and rain in moving soil from one part to another and the substitution of new surface soil by the upraising of a certain amount of material from deeper strata.

Being composed partly of inorganic matter derived from the subsoil by the process of weathering, and partly of the products of decomposition of animal and vegetable matter, most soils contain in abundance the compounds which plants require, such as nitrogen, lime, potash, soda, magnesia, silica, and phosphoric acid ; but these substances are in an insoluble condition and only rendered assimilable by plants, after a slow conversion into soluble compounds by the agency of various forms of bacteria. This process, combined with the decomposition of vegetable remains, results in the formation of the so-called "humus." Very little is known with regard to the exact composition of humus. Some attempts have been made to separate it into constituent parts, and certain acids have been found, some of which, such as Crenic acid, are soluble in both water and alkalies ; others, such as Humic acid, being insoluble in water but soluble in alkalies ; whilst others again, such as Ulmic acid, are insoluble in both water and alkalies.

The colour of humus is said to depend upon the nature of the acid present, ulmic acid giving a brown, and humic acid a black mould.

SOIL FEATURES WHICH INFLUENCE CLIMATE AND HEALTH.

There are certain general features of soil which materially influence both climate and health ; they are, its Conformation and Elevation, the amount of Vegetation present upon it, its contained Air and Water, its Temperature and power for absorbing or retaining Heat, and lastly, the nature and number of its contained Micro-organisms.

Conformation and Elevation.—The relative amounts of hill and plain ; the elevation of the hills ; their direction ; the angle of slope ; the kind, size, and depth of valleys ; the chief watersheds, and the direction and discharge of the water-courses ; the amount of fall of plains ; these are the chief points to be considered.

Among hills the unhealthy spots are enclosed valleys, punch-bowls, and any locality where the air must stagnate, such as ravines or places at the head or entrance of ravines. In the tropics especially ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and frequently traversed by high winds. During the heat of the day the current of air is up the ravine, at night down it. As the hills cool more rapidly than the surrounding plains, the latter current is especially objectionable, as the air is cold. The worst ravine is a long narrow valley, contracted at its outlet, so as to dam up the water behind it. A saddleback is usually healthy, if not too much exposed ; so are positions near the top of a slope. One of the most difficult points to determine in hilly regions is the probable direction of winds ; they are often deflected from their course, or the rapid cooling of the hills at night produces sudden changes in temperature.

On plains the most dangerous points are generally at the foot of hills, especially in the tropics, where the water, stored up in the hills and flow-

ing to the plain, causes an exuberant vegetation at the border of the hills. A plain at the foot of hills may be healthy, if a deep ravine cuts off completely the drainage of the hill behind it. The next most dangerous spots are depressions below the level of the plain, and into which therefore there is drainage. Even gravelly soils may be damp from this cause, the water rising rapidly through the loose soil from the pressure of higher levels. Elevation acts chiefly by its effect in lessening the pressure of the air, and in increasing the rapidity of evaporation.

Vegetation.—The effect of vegetation on ground is very important. In cold climates the sun's rays are obstructed, and evaporation from the ground is slow; the ground therefore is cold and moist, and the removal of wood and undergrowth renders the climate milder and drier. The extent to which trees impede the passage of water through the soil is considerable.

In hot countries, vegetation is of advantage as shading the ground and making it cooler. It is notorious that the hottest and driest places in the tropics are those divested of trees. Herbage is always healthy; in the tropics, it cools the ground both by obstructing the sun's rays and by aiding evaporation; on the other hand excessive brushwood is often a disadvantage in that it obstructs air movement and tends to harbour flies and other insects. Trees at all times are an advantageous feature and need to be removed with judgment. In cold countries they shelter from winds, while in hot countries they cool the ground. The kind of vegetation, except as being indicative of damp or dry soil, does not appear to be of importance.

Ground Air.—The hardest rocks alone are perfectly free from air; the greater number even of dense rocks, and all the softer rocks and the loose soil covering them, contain air. The amount is, in loose sands, often 40 or 50 per cent.; in sandstones 30 per cent.; while in garden loam and the lighter soils it may even reach 70 per cent.

The nature of the air in soils has been examined by many observers; it is mostly very rich in carbon dioxide, is very moist, and frequently contains the effluvia of organic substances. Occasionally it contains carburetted hydrogen, and in moist soils, when the water contains sulphates, a little hydrogen sulphide may be found.

Pettenkofer was one of the first to point out the excess of carbon dioxide in ground air, as compared with that in atmospheric air. According to him, the amount increased with the depth from which the air was drawn, and was moreover much influenced by the season of the year, the greatest quantity, at a given depth, being obtained in July, and the least in January. This was at Munich. Fodor, at Buda-Pesth, and Fleck, at Dresden, obtained very similar results. Both Pettenkofer and Fleck were of opinion that this carbon dioxide was due to the decomposition of organic substances, and that it might afford an approximate index of the degree of soil pollution. Fodor, however, showed that a very foul soil, if at the same time permeable, contains less carbon dioxide than a cleaner but less permeable soil; and suggested that although the carbon dioxide is probably produced by the decomposition of organic matters, it does not afford so much a means of estimating the degree of pollution as of the permeability of the soil. Another source of carbon dioxide in soil air is the decomposition of carbonates in the soil by an acid, this latter being produced by the oxidation of pyrites which exist in an easily oxidisable form, as marcasite.

Lewis and Cunningham, in their observations at Calcutta, found results somewhat similar to those of Fodor, the carbon dioxide being greatest in the lower strata examined. The carbon dioxide increased with the rainfall,

the effect of the rain being to close the pores in the upper layers of the soil, and so retain the carbon dioxide. Soil temperature they did not consider to have any effect. The composition of soil air differs at different times and seasons, the absolute and relative amounts of the constituents varying under varying conditions.

Just as the carbon dioxide increases so does the amount of oxygen decrease with the depth from which the soil air is withdrawn. Some figures given by Fodor gave from 18 to 21 per cent. of oxygen at a depth of 1 metre, and 18 per cent. at 4 metres. In some freshly manured moist soil, Boussingault found the percentage of carbon dioxide to be as much as 9·5, and that of oxygen only 10. From this it would seem that, on air passing into soil, its oxygen enters into chemical combination with carbon derived from animal and vegetable matter, and thus becomes replaced by an equal volume of carbon dioxide. However, this is not always the case, as occasionally the percentage amounts of oxygen and carbon dioxide together in soil air are such as to suggest the possible union of some of the oxygen with the hydrogen to form water, and with nitrogen to form nitrates; while the carbon dioxide which is formed may dissolve in the soil water or unite with bases to form bicarbonates. On the other hand, Blount records a case where, in spite of acid derived from oxidation of pyrites in the presence of carbonates, no carbon dioxide was present in the soil air. This was due to the fact that the air, being under pressure, passed through the soil too rapidly for the secondary products to be formed from the carbonates.

The marked effect of rainfall and heat upon the amount of carbon dioxide in the soil is probably due to a blocking up of the pores of the superficial soil layers, synchronous with an increased production whereby an accumulation of carbon dioxide takes place in the deeper portions. The presence of much moisture in a soil is invariably coincident with a fall in the amount of carbon dioxide in the soil air owing to absorption by the water. Some daily variations of carbon dioxide in the ground air have been noticed, but appear to depend less upon processes of soil activity than on rain, wind, and changes of atmospheric pressure. These two latter do not appear to exert any very great influence, and are evidently secondary to rainfall as factors in the greater or less existence of carbon dioxide in soil air.

The *nitrogen* present in the ground air is almost constant, being the same as that in the atmosphere, namely, about 79 per cent. Besides oxygen, nitrogen, and carbon dioxide, the ground air contains about 85 per cent. of humidity, together with various products of fermentation and decomposition, such as ammonia, ammonium sulphide, hydrogen sulphide, and marsh gas; these latter, however, rarely existing in large amounts. Owing to the constant reduction, in the soil, of the various oxidised states of nitrogenous organic substances into ammonia, under the influence of bacteria, this gas, although present in the ground air, cannot be taken as an index of either pollution or putrefactive changes.

The subterranean atmosphere, thus existing in many loose soils and rocks, is in continual movement, especially when the soils are dry; the chief causes of movement are the diurnal changes of heat in the soil, and the fall of rain, which must rapidly displace the air from the superficial layers, and, at a later date, by raising the level of the ground water, will slowly throw out large quantities of air from the soil.

Local conditions must also influence the movement; a house artificially warmed must be continually fed with air from the ground below, and doubtless this air may be drawn from great depths. Coal gas escaping from pipes, and prevented from exuding by frozen earth on the surface, has

been known to pass sideways for some distance into houses. The air of cesspools and of porous or broken drains will thus pass into houses, and the examination of drains alone often fails to detect the cause of effluvia in the house.

The unhealthiness of houses built on "made soils," for some time after the soils are laid down, is no doubt to be attributed to the constant ascent of impure air from the impure soil into the warm houses above. To hinder the ascent of air from below into a house is therefore a sanitary point of importance, and should be accomplished by paving and concreting, or asphalting the basement, or, in some cases, by raising the house on arches off the ground. The improvement of the health of towns, after they are well paved, may be partly owing to lessening of effluvia, though partly also to the greater ease of removing surface impurities. As a rule, it is considered that loose porous soils are healthy, because they are dry, and, with the qualification that the soil shall not furnish noxious effluvia from animal or vegetable impregnation, the rule appears to be correct. Even on the purest soils it is desirable to observe the rule of cutting off the subsoil air from ascent into houses.

The amount of air in soils can be roughly estimated, in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by the following plan :—Take a measured quantity of soil, say 50 c.c., shaken well together, so as to represent its natural condition as much as possible, and put it into a 200 c.c. graduated glass measure ; then pour in 100 c.c. of water, and shake well so as to expel all air. Allow it to stand a little and read off the point at which the water stands. Suppose it stands at 125 c.c., then the 50 c.c. of soil and the 100 c.c. of water, when shaken together, only occupy a space of 125 c.c., the difference, 25 c.c., representing the bulk of air displaced from the 50 c.c. of soil ; therefore $\frac{25}{50} \times 100 = 50$ per cent. of air or porosity in the sample of soil.

The examination of soil air can be best carried out by inserting into the soil leaden or iron tubes provided at their ends with perforated bulbs. To facilitate the introduction of these tubes, a hole must be dug, in the bottom of which broken bricks or large stones should be placed, and the bulbed ends of the tubes fixed at varying depths among them, the pit being afterwards filled and rammed in with the displaced soil. It is advisable that the disturbed earth be allowed to remain a month or more before observations are made, so as to allow the soil to regain its ordinary condition. The tubes so placed in the earth should be next connected with an aspirator, capable of holding 2 litres or more of air ; while intervening between the tubes and the aspirator must be arranged the usual appliances for the estimation of carbon dioxide, of oxygen, organic matter or micro-organisms in air. It is not necessary here to describe any of these procedures, as they are explained in another chapter ; it is sufficient to point out that the essence of these arrangements is to be able to extract air from varying soil depths and then cause it to pass over or into certain re-agents, contained in suitable apparatus, so as to complete the determination required.

Ground Water.—The water present in soils is divided into moisture and ground water. When air as well as water is present in the interstices the soil is merely moist. The ground water may be defined, after Pettenkofer, as that condition in which all the interstices are filled with water, so that, except in so far as its particles are separated by solid portions of soil, there is a continuity of water. Other definitions of ground water have been given, but it is in this sense it is spoken of here.

Moisture of Soil.—The amount of moisture depends on the power of the soil to absorb and retain water, and on the supply of water to the soil either from rain or ground water. With respect to the first point, almost all soils will take up water. Pfaff has shown that dried quartz sand in a filter can take up as much as 20 per cent. of water, and, though in the natural condition in the soil the absorption would not be so great, there is no doubt that even the hardest sands retain much moisture. After several months of long-continued drought, Church found a light calcareous clay loam subsoil to contain from 19 to 28 per cent. of water.

A loose sand may hold 2 gallons of water in a cubic foot, and ordinary sandstone may hold 1 gallon. Chalk takes 13 to 17 per cent. ; clay, if not very dense, 20 ; humus, as much as 40 to 60, and retains it strongly. The so-called "cotton-soil" of Central India, which is derived from trap rock, absorbs and retains water with great tenacity ; the driest granite and marbles will contain from 0·4 to 4 per cent. of water, or from 5 to 50 pints in each cubic yard.

The moisture in the soil is derived partly from rain, to which no soil is absolutely impermeable, as even granite, clay slate, and hard limestone may absorb a little. Practically, however, soils may be divided into the impermeable (unweathered granite, trap and metamorphic rocks, clay slate, dense clays, hard oolite, hard limestone and dolomite, &c.) and the permeable (chalk, sand, standstone, vegetable soils, &c.). The amount of rain passing into the soil is influenced, however, by other circumstances—by the declivity and inclination of the soil ; by the amount of evaporation, which is increased in summer ; by hot winds ; and by the rapidity of the fall of rain, which may be greater than the soil can absorb. On an average, in this country, about 25 per cent. of the rain penetrates into the sand rock, 42 per cent. into the chalk, and from 90 to 96 per cent. into the loose sands. The rest evaporates or runs off the surface by the lines of natural drainage. The rapidity with which the rain-water sinks through soil evidently varies with circumstances ; in the rather dense chalks it has been supposed to move 3 feet downwards every year, but in the sand its movement must be much quicker.

The moisture of the soil is not, however, derived solely from rain ; the ground water by its own movement of rising and falling, by evaporation from the surface of the subterranean water, and by capillary attraction makes the upper layers of the soil wet. By these several agencies the ground near the surface is in most parts of the world kept more or less damp.

In the superficial soil layers, the capillary action appears to be greatest for clays and least for chalks ; humus and sand occupying an intermediate position.

As regards the affinity of soils for water and their capabilities for moisture, a distinction must be made between the permeability and absorptive power of a soil. A permeable soil, by allowing water or moisture to pass through it, contributes to the supply of the ground water, while an absorptive soil really retains the moisture. Miers and Crosskey have explained the action of the soil in regard to water as being of a threefold nature. They say, it may act merely as a strainer allowing fluid to pass through itself ; it may take up water just as blotting paper takes up ink ; or it may be saturated by water and retain it, as a sponge, immersed in water, is saturated by liquid which flows from it when the sponge is lifted out. This involves a distinction between *permeability*, *imbibition* and *saturation ;* because the amount of water which percolates through the soil is due to its permeability, that which is retained as moisture in the soil is

due to its power of imbibition, while that lying in the subsoil, in the form of ground water, depends upon the saturation. Practically, the relation to water of a given soil depends upon all these three qualities, and according as the one or other is most prominent, so will the soil be drier or damper.

Thus, sandstones are very permeable but not absorptive, the same is the case with the limestones, chalk and schistose rocks. Generally speaking, soils which possess a great capacity for imbibition are not very permeable, and conversely the most permeable soils have the least storage capacity. The best test of permeability of a soil will be the rapidity with which percolation takes place through it. A number of experiments made indicate that water passes through clay the most slowly, and gradually increases in rapidity through marls, granitic soils, loams, limestone, coarse sand, basaltic soil, and fine sand. Warrington found that at Rothamsted only 7 inches of rain, out of an annual fall of 28 inches, percolated, during the year, through 3 feet of clayey gravel; while Prestwich relates that "on the chalk hills it takes four to six months for rain to pass from the surface to the line of water-level at the depth of 200 to 300 feet, so that the heavy rainfall of winter is not felt in the deep springs for some months."

Regarding the value of a rock or soil as a water-bearing stratum being mainly dependent upon its capacity for saturation, the following figures from Delesse are interesting :—

Sandstone	will	retain	29	per cent.	of water.
Chalk	,,	,,	24	,,	,,
Clay	,,	,,	20	,,	,,
Clay with chalk	,,	,,	19	,,	,,
Basalt	,,	,,	0·3	,,	,,
Granite	,,	,,	0·1	,,	,,

The determination of moisture in soil can be made by drying 10 grammes at a temperature of 110° C., then weighing, when the difference of the two observations will represent the amount sought. The quantity of moisture which a given soil sample is capable of taking up may be determined by placing the previously dried soil under a bell-jar over water and noticing the resulting increase of weight.

The amount of actual moisture found in soils appears to vary with the depth and the amount of contained organic matter being diminished as deeper layers are penetrated and as the quantity of organic material decreases, The moisture varies not only from year to year, but from month to month, reaching, in Europe, generally a maximum in May and then falling during the summer until late autumn. In the deeper soil layers, the maximum of moisture is not attained till midsummer. The minimum found by Fodor * in Buda-Pesth at 1 metre was 5·9 per cent., while at 4 metres it was 3·2 per cent. Decomposition, in soil, ceases when the moisture falls below 1·5 per cent., but is most active when the amount is about 4 per cent. A sample of surface soil, taken at 6 inches, consisting of loose sandy loam, examined by one of us in India, contained but 2 per cent. of moisture.

The Ground or Subsoil Water.—The subterranean continuous water, known as *ground or subsoil water*, is at very different depths below the surface in different soils; sometimes it is only 2 or 3 feet from the surface, in other cases as many hundreds. This depends on the compactness or permeability of the soil, the ease or difficulty of outflow, and the existence or not of an impermeable stratum near or far from the surface. It is an error to look upon the ground water as a subterranean lake or sea, with an even surface like an ordinary sheet of water, for it is not necessarily

* Fodor: *Hygienische Untersuchungen über Boden, Luft und Wasser*, Braunschweig, 1882.

horizontal, and in some places it may be brought nearer to the surface than others by peculiarities of ground. This water is in constant movement, in most cases flowing towards the nearest water-courses or the sea, the rate of movement varying much in different localities.

The rate of movement is not influenced solely by compactness or porosity of soil, or inclination. The roots of trees exert a great influence in lessening the flow ; and, on the other hand, water runs off more rapidly than before in a district cleared of trees. The level of the ground water is constantly changing. It rises or falls more or less rapidly and at different rates in different places ; in some cases its movement is only a few inches either way, but in most cases the limits between its highest and lowest levels in the year are several feet (in Munich about 10). In India the changes are greater. At Saugor, in Central India, the extremes of the soil water are from a few inches from surface (in the rains) to 17 feet in May. At Jubbulpore it is from 2 feet from the surface to 12 or 15. At Calcutta, Lewis and Cunningham found the water-level to vary between 5 and 15 feet below the surface.

The *causes of change* in the level of the ground water are the rainfall, pressure of water from rivers or the sea, and alterations in outfall, either increased obstruction or the reverse. The effect of the rainfall is sometimes only traceable weeks or even months after the fall, and occasionally, as in plains at the foot of hills, the level of the ground water may be raised by rainfalls occurring at great distances. A uniformly low ground water, say 15 to 20 feet, is most healthy, but a uniformly high ground water, say 3 to 5 feet, is preferable to one that is fluctuating, especially if the limits be wide. It must, however, be borne in mind that it is not the ground water itself that is the cause of disease, but the impurities in the soil which the varying level of the ground water helps to set in action.

Measurement of the Ground Water.—The height at which water stands in wells is considered to give the best indication of the height of the ground water. We have used a large float, suspended by a chain or rope travelling over a pulley; if a balancing weight be attached to the other end, this serves as an indicator working over the face of a fixed scale. Some precautions are necessary in making these observations ; if a rope is used, it may stretch with use, or in a hot dry wind, or contract in wet weather, and thereby make the observation incorrect ; local conditions of wells, proximity to rivers, &c., must be learnt, else what may be termed local alterations in a well may be wrongly supposed to mean changes in the general level of the ground water. It is necessary, therefore, to make the observations simultaneously in many wells and over a considerable district. The observations should be made not less often than once a fortnight, and oftener if possible, and be carried on for a considerable time before any conclusions are drawn.

Method of rendering Soil Drier.—There are two plans of doing this—deep drainage and opening the outflow. The laying down of sewers often carries off water by leaving spaces along the course of the sewers, but this is a bad plan ; it is much better to have special drains for ground water laid by the side of or under the sewers. Deep soil drainage (the drains being from 8 to 12 feet deep and 10 to 20 feet apart) is useful in all soils except the most impermeable, and in the tropics should be carried out even on what are apparently dry sandy plains.

In some cases soil may be rendered drier by opening the outflow. This is an engineering problem which medical officers can only suggest. The clearing of water-courses, removal of obstructions, and formation of fresh channels are measures which may have an effect over very large areas which could not be reached by ordinary drainage.

Soil Heat.—Under this heading is involved the questions of the capacity of soils for both absorbing, retaining and giving off heat, as well as the facts regarding mere soil temperatures. It is a matter of common knowledge that certain soils are warmer than others, that is, they are more easily heated by the sun's rays, or, in other words, have a lesser or greater *specific heat*. The specific heat of water is usually taken as unity, and on this basis the various soils have a distinctly lower specific heat than water, and consequently are more easily warmed than water. In this connection, the two following tables, quoted by Lloyd from experiments made by Liebenberg of Halle, are of interest:—

Gain of Heat by Soils.

	Original Temperature.	After ½ hour.		After 1 hour.		After 2 hours.	
		2 cm.	5 cm.	2 cm.	5 cm.	2 cm.	5 cm.
Lime sand . .	21° C.	29° C.	27°·5 C.	32° C.	31°·5 C.	36°·5 C.	37°·0 C.
Tertiary clay . .	21°	30°	27°·5	33°	30°·0	36°·3	35°·0
Tertiary sand . .	21°	30°	28°·0	33°	32°·5	37°·5	36°·5
Marl . . .	21°	31°	28°·5	34°	32°·5	39°·0	37°·5
Meadow loam . .	21°	32°	27°·5	37°	36°·0	40°·5	38°·5
Rich loam . .	21°	32°	29°·0	36°	34°·0	41°·5	39°·5
Basalt . . .	21°	33°	28°·5	35°	33°·0	42°·0	38°·0
Water . . .	21°	26°	26°·0	29°·5	29°·5	31°·0	31°·0

Loss of Heat by Soils.

	Original Temp.	After ½ hour.	After 1 hour.	After 2 hours.
Coarse sand	41°·25 C.	29°·75 C.	24°·25 C.	19°·75 C.
Fine sand	41°·75	28°·25	23°·25	18°·75
Marls	40°·00	27°·50	23°·00	18°·50
Loams	40°·00	27°·00	22°·00	18°·00
Clay	39°·50	26°·00	21°·50	18°·00

These tables show that not only does sand warm much more rapidly than clay, but also that the presence of organic matter in any soil causes it to possess a relatively greater power of absorbing heat. These facts are probably due to the peculiar behaviour of water to heat. Water is both a bad absorber and bad radiator of heat, hence soils which contain much water, such as a damp clay, have a higher specific heat than dry porous soils, like sand, and consequently warm slowly and are often spoken of as "cold soils." This is in accordance with everyday experience.

The rapidity with which soils radiate heat is not necessarily equal to their power of absorbing it, but will depend somewhat on their colour and the kind and thickness of the vegetation growing upon them. It is notorious that dark materials always absorb more radiant heat than light ones; "it has been found, for instance, that with the same exposure to the sun, a white sand attained a temperature of 43° C., while a black sand rose to 50° C." Generally the radiating power is more rapid than the absorbing; hence soils cool more rapidly than they heat.

It will be readily understood, from the above considerations, that the temperature of the soil is but rarely that of the atmosphere, but more often higher; and, too, that the earth's temperature is different in different places. Fodor was one of the first, from his observations made at Buda-Pesth, to point out that the surface soil is warmer by day and colder by

night than the air, but that the subsoil reaches its maximum and minimum heat later than the surface soil, so that it is colder in summer but warmer in winter than the superficial layers.

Fodor's results and those of others indicate the greatest range of temperature in the superficial soil; at 18 inches below the surface there occurs, in Europe, a variation of from 15° to 20° C. below the monthly mean, while at 10 feet deep the variation is as little as from 3° to 5° C.

There is marked difference in the manner in which the *surface* soil temperatures follow variations in the atmospheric heat, as compared with the temperatures of the deeper layers. While the temperature of the surface soil will quickly respond to small changes in heat of the air, that of the soil below the surface follows even great variations of air temperature but slowly. Thus, after a series of cold or warm days, it will be three or more days before the soil temperature, at a depth of half a metre, will accommodate itself to that of the air. At greater depths the stability of the soil temperature is even greater.

The sun's rays would appear to cause two currents of heat in soil; one wave is diurnal, the heat passing down in temperate climates to about 4 feet in depth during the day, and receding during the night, the depth, however, varying with the nature of the soil and with the season; the other wave is annual, the amplitude of which diminishes with the depth till it ceases to be perceptible. Forbes has shown, from observations made in Edinburgh, that the annual variation is not appreciable lower than 40 feet below the surface, and that under 24 feet the changes of temperature are small through the year. The depth at which the annual variation ceases, or where the temperature is constant, depends on the conductivity and specific heat of the soil; but particularly on the difference between the summer and winter temperatures. The rate at which the annual wave of heat is propagated downwards is so slow, that at Edinburgh, at a depth of 24 feet, the highest annual temperature does not occur till January, and the lowest not till the middle of July; thus reversing the seasons at this depth. At Greenwich, at 25½ feet, these phases of the annual temperature occur on November 30 and June 1. Some observations made in the Punjab showed that at 20 feet the annual maximum was reached in September and the minimum in March. According to Everett, the heat of the earth's surface is not influenced by the flow of heat from below upwards, but is determined entirely by atmospheric conditions. The temperature gradient averages an increase of heat downwards of 1° F. for each 50 feet roughly, which makes the soil heat gradient five times steeper than that of air. The soil temperature gradient is steepest beneath gorges and least so beneath ridges; hence the underground isothermals (annual) are flatter than the uneven surfaces above them. The increase or extension of heat through any cubic area of soil is about equal to the product of the temperature gradient by the conductivity, so that it includes convection by the percolation of water as well as conduction proper; as a result of this, in comparing different strata of soil, the heat gradient varies in the inverse ratio of the soil conductivity.

In Calcutta, Lewis and Cunningham found that the temperature of the soil varied with the season. In hot weather the thermometer stood highest in the air, next highest in the upper stratum of the soil, and lowest in the lower stratum. In cold weather the conditions were exactly reversed, the air being coolest and the lowest stratum of soil the hottest. During rain, however, these relations were not constant.

Since the effect of cold, generated by nocturnal radiation, mostly accumulates on the earth's surface, while the effects of solar radiation are

spread to some height by ascending currents from the heated ground, it might be expected that the mean annual temperature of the soil surface would be lower than that of the air resting on it; this is precisely what is found to be the case. On the other hand, the deeper layers of the earth are often warmer than the atmosphere, and do not display the same extremes of heat as does the air. This is seen in the case of deep springs which get their source from depths greater than that to which the annual variation of soil heat penetrates, and have in consequence a constant temperature throughout the year, and further, if they come from a depth much greater, they give a close approximation to the mean annual temperature of the place.

Reflection of Light.—This is a matter of colour; the white glaring soils reflect light, and such soils are generally also hot, as the rays of heat are also reflected. The effect of glare on the eyes is obvious, and in the tropics this becomes a very important point. If a spot bare of vegetations, and with a white surface, must be used for habitations, some good result might be obtained by colouring the houses pale blue or green.

The effect of soil temperature upon disease production is doubtless important, affecting chiefly the ability of various micro-organisms to survive in the earth at varying depths.

Estimation of Soil Temperatures.—No difficulty should be experienced in making these observations. One or more shafts or tubes should be bored into the soil to the required depth; the sectional diameter of these tubes may vary from 2 to 8 inches. Into the tubes, boards or blocks of wood should be made to fit, carrying the thermometers at suitable depths; the opening or mouth of the tube being closed with an accurately fitting cap or plug. The observations should be taken at the same hour every day, the thermometers immediately returned into the soil, care, of course, being taken, before so doing, to raise the registering index of the minimum, and to depress that of the maximum instrument well above and below the temperature of the soil.

Micro-organisms in Soil.—For some years it has been known that ordinary garden soil and agricultural humus contain large numbers of micro-organisms. Schlösing and Muntz in 1877-78, and Warrington about the same time, showed that the process of nitrification which takes place in soils is a fermentative process, excited and carried on through the agency of bacteria, just as ordinary fermentation is carried on by *torula.* Miquel in 1897 attempted to estimate the number of germs present in soils of different kinds. Since then, Koch, Fränkel, Flügge, the Franklands, and other observers have pursued the subject, which opens out a large field for investigation of great importance; these researches have yielded results from which some conclusions may be drawn, though this should only be done with caution.

The existence of micro-organisms in soil is not surprising, when one considers that in many kinds of ordinary soil all the conditions necessary for their growth and multiplication are present, namely, a supply of nutritive substance derived from the decomposition of organic matter, moisture, access of air, and a suitable temperature. All of these conditions are commonly found in the superficial much more than in the deeper layers of the soil, and it is accordingly in the former rather than in the latter that microbes are found to exist in the greater numbers; below 12 to 15 feet in depth they are comparatively few. The greater the organic pollution of the soil, the greater the number of microbes present; the most suitable conditions of moisture and temperature no doubt vary in regard to different species, neither dryness nor complete saturation, nor the extremes of heat and cold

being favourable to the development of many forms at present investigated. The actual numbers of germs found, or calculated by different observers, vary very considerably, and are perhaps of not much importance, but there is a pretty general agreement in regard to these two points :—(1) the larger the amount of organic matter in the soil, the greater the number of micro-organisms ; (2) whatever the nature of the soil, the number of micro-organisms diminishes as the depth increases.

All forms of bacterial life have been found to be present in soil ; in the moist and superficial layers, micrococci are the more numerous, while in the drier and deeper portions, bacilli are present in the largest numbers. As Flügge has shown, some species are markedly prominent, and are found in the most varied places, while others occur in only limited areas. It is probable that large numbers and kinds of bacilli are also present in the soil in the form of spores. Practically all the micro-organisms found in soil may be divided into the *saprophytic* and the *pathogenic*.

The former probably includes a large number of species, which up to the present have not been differentiated ; according to Arnould, no more precise distinction can be drawn than between those which *oxidise*, and those that *de-oxidise* or *reduce*. Of these the oxidisers are the most numerous and important, including those through whose agency the process of nitrification takes place ; this, though originally supposed to be the work of one specific "nitrifying ferment," is in all probability effected by several different forms. Nitric and nitrous organisms are now distinguished from each other by specific characters. The *Bacillus mycoides* and the *Bacillus fluorescens liquefaciens* have been found to have a powerful reducing action on nitrates. Possibly the same species may be at one time an oxidiser, at another a reducing ferment.

The pathogenic bacteria occur with such frequency in the earth that no material produces infection so easily as soil. Well-known pathogenic inhabitants of the soil are the bacilli of malignant œdema, of infective tetanus, and the anthrax bacillus. With soil, too, are probably often associated Eberth's bacillus of enteric fever, the vibrio of cholera, some forms of streptococci, and the *B. enteritidis sporogenes*, said by Klein to be connected with the occurrence of epidemic summer diarrhœa. The local and seasonal variations in the distribution of some infective diseases led Pettenkofer and others to believe that the soil had a specific influence on the development and spread of infective germs, and that there was a constant connection between soil and epidemics ; it is doubtful, however, whether this view is correct, except in regard to a limited number of pathogenic bacteria. The truth probably is that on the surface of the soil pathogenic bacilli find such conditions of moisture and temperature as are favourable to their germination and the production of new bacilli ; but that they speedily cease to exist, the vegetative form being easily overcome by saprophytes. The deeper layers of the soil, on the other hand, are favourable for the preservation of the spore-bearing species, though not for their multiplication ; it is because they do not develop, but remain in the spore form, the temperature and other surrounding circumstances being unsuitable to germination, that they are preserved, vitality being maintained, though dormant.

Soyka's experiments with anthrax bacilli indicate that, in their case at least, the soil exercises no marked or specific influence on the formation of spores. Observations made with other pathogenic forms similarly show the soil to be deficient in any special power of furthering spore formation. The preservation of non-spore-bearing bacteria in soil has been explained by

Sovka as likely to occur often, because in that medium they are rarely likely to become completely dried, even in the driest of soils, owing to the layer of aqueous vapour which so tenaciously surrounds the elements of the soil. The length of life of micro-organisms in the soil depends almost entirely on the amount of moisture present. Peat appears to be very hostile to many forms of bacteria; why so, is not precisely known, but is very generally attributed to the presence of complex acids. Even granting the frequent preservation of pathogenic bacteria in soil, it must be remembered that this preservation is not an exclusive attribute of soil, and that, in the case of the infective diseases, this action or want of action of the soil can but rarely influence the spread of epidemics.

Much interest attaches to the question, How do the preserved bacteria spread from the soil to man? The action of winds and the blowing about of bacteria-laden dust is only conceivable from the superficial layers of very dry soils. In some countries, notably in the East, and especially where excreta are superficially dug into or carelessly spread upon the ground, wind action probably is a more potent factor in the spread of disease than is generally recognised. In this country and Europe generally the possibility of a detachment and carrying away of soil bacteria by currents of air is only present in the latter end of summer, or in autumn, and quite absent when rain renders the outer surface of the earth moist.

In estimating the value of the ground water and the water derived from it for drinking and other purposes, as means of distributing soil bacteria, we must take into consideration the enormous capacity of soil for retaining, as it were in a mesh, even such minute bodies as bacteria. The soil is, in fact, an excellent microbic filter, and "where there is a thick layer of soil above the ground water, this mode of transport cannot come into play"; but where the ground water is only separated by thin layers of loose soil from the surface, or when fissures or cracks permit a ready communication between cesspools and wells, then the bacteria will pass from the soil to man. Although the soil acts as a good filter, holding back most of the organisms, Dempster has demonstrated that it is possible for cholera commas to be carried through two feet and a half of porous soil by a current of water. Occasionally micro-organisms may be conveyed from the soil to the domestic economy by articles of food which grow in the soil, or by animals, but such modes of transference must obviously be the exception rather than the rule.

The most important result of the presence of micro-organisms in soil appears to be the carrying on of a process of oxidation of the dead organic matter that finds its way into the ground, the process of *nitrification* that has already been alluded to; the nitrogen of organic bodies is first turned into ammonia, and this is successively changed into nitrites and nitrates. That this action was due to some property residing in the soil itself was shown by the experiment of Schlösing; if a weak solution of ammonia is applied to a mixture of calcined sand and chalk and freely exposed to the air, no oxidation will take place, even after several weeks; if then a morsel of garden soil be added, in a few days nitrites and nitrates will be detected. This action is entirely arrested by the introduction into the soil of vapour of chloroform, which paralyses all fermentative organisms. The nitrifying power of different soils varies very considerably, depending partly on the nature of the soil itself, partly on the amount of ferment present (this in turn depending both on the number and nature of the micro-organisms), and being affected also by conditions of temperature and moisture. It appears to be of the first necessity that the soil should be alkaline, the carbonates of

26

potash and lime being the most usual constituents, and after these, lime and magnesia; a quartz sand without lime is unfavourable to nitrification. The most favourable temperature is 37° C. The soil must be moist, and must also be penetrated by air; the successful purification of sewage by the method of intermittent downward filtration, as compared with filtration from below upwards, depends upon this; by the latter method the access of air is prevented and nitrification retarded. Along with the oxidation of nitrogenous organic matter into nitric acid proceeds the oxidation of organic carbon into carbonic acid, the one action being in fact the complement of the other.

THE COMPARISON OF DIFFERENT SOILS.

In examining the influence upon health of the soil round any dwelling, it is probable that the immediate local conditions are of more importance than extended geological inquiries; it is, so to speak, the house and not the regional geology which is of use. Still the general geological conditions, as influencing conformation and the movement of water and air through and over the country, are of great importance. The healthiness of a soil depends chiefly on the following factors:—(1) considerable slope and permeability, so that water runs off readily and regularly, rendering both the soil and the air above it dry; (2) vegetation not excessive; (3) absence of organic emanations; (4) purity of water-supply. In reference to these points, the different soils can be thus critically examined.

The Granitic, Metamorphic, and Trap Rocks.—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent, and few impurities pass into the drinking water.

When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; but evidence as to the effect of disintegrated granite or trap is really wanting.

The Clay Slate.—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much slope; are very impermeable; vegetation is scanty; and nothing is added to air or to drinking water. They are consequently healthy. Water, however, is often scarce; and, as in the granite districts, there are swollen brooks during rain, and dry water-courses at other times, swelling rapidly after rains.

The Sandstones.—The permeable sandstones are very healthy; both soil and air are dry; the drinking water is, however, sometimes impure, and may contain large quantities of chlorides, especially in the New Red Sandstone when rock-salt abounds. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp.

Carboniferous Formations.—The hard millstone grit formations are very healthy, and their conditions resemble those of granite. The drinking water is generally pure and fairly soft.

The Limestone and Magnesian Limestone Rocks.—These so far resemble the former that there is a good deal of slope and rapid passing off of water. Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water. The drinking water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst.

The Chalk.—The chalk, when unmixed with clay and permeable, forms a very healthy soil. The air is pure, and the water, though charged with calcium carbonate, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts.

If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often marshy and malarious.

Gravels of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites, and the water, which often flows out in springs near the base, is usually pure.

Sands.—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter and are of considerable depth. The air is pure, and so is often the drinking water. Sometimes the drinking water contains enough iron to be unpleasantly chalybeate.

In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable layer from higher levels. Water may then be found within 3 or 4 feet of the surface; and in this case the sand is unhealthy and often malarious.

In a third class of cases the sands are unhealthy because they contain soluble mineral matter. Many sands (as, for example, in the Punjab) contain much magnesium carbonate and lime salts, as well as salts of the alkalies. The drinking water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts and iron. Without examination of the water it is impossible to detect these points.

Clay, Dense Marls, and Alluvial Soils generally.—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often alternations of thin strata of sand and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure.

The deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by the drainage of even a small area.

Cultivated Soils.—Well-cultivated soils are often healthy, nor at present has it been proved that the use of manure is hurtful. Irrigated lands, especially in warm climates, owing to their favouring the prevalence of mosquitoes, are objectionable in the vicinity of habitations. In India and other tropical countries this point should not be overlooked.

Made Soils.—The inequalities of ground which is to be built upon are frequently filled up with whatever happens to be available. Very often the refuse of a town, the cinders or dust-heaps, after being raked over and any saleable part being removed, are used for this purpose. In other cases chemical or factory refuse of some kind is employed. The soil under a house is thus often extremely impure. It appears, however, that the organic matters in soil gradually disappear by oxidation and removal by rain, and thus a soil in time purifies itself. The length of time in which this occurs will necessarily depend on the amount of impurity, the freedom of access of air, and the ease with which water passes through the soil. In the soil at Liverpool, made from cinder refuse, vegetable matters disappeared in about three years; textile fabrics were, however, much more permanent; wood, straw, and

cloth were rotten and partially decayed in three years, but had not entirely disappeared. In any made soil it should be a condition that the transit of water through its outlet from the soil shall be unimpeded. The practice of filling up inequalities is certainly, in many cases, very objectionable, and should only be done under strict supervision.

SOIL IN RELATION TO SPECIAL DISEASES.

There are certain diseases of both animals and man, with the etiology of which the soil or the conditions of its contained air, water, and micro-organisms, from time to time, have appeared to bear some connection. The diseases are—anthrax, calculus, cancer, cholera, epidemic diarrhœa, diphtheria, dysentery, enteric fever, goitre, lead poisoning, malaria, malignant œdema, phthisis, rheumatism, rickets, tetanus, and yellow fever. While in the case of several nematoid worms known to be parasitic to man, it is probable that the soil constitutes their normal habitat, in at least one stage of their existence.

Anthrax.—Known in man, under the forms of malignant pustule and woolsorters' disease, this is a specific affection communicable to human beings directly or indirectly from the lower animals, especially the herbivora. Of all the pathogenic micro-organisms, the specific bacillus of this disease is probably the one whose history and characters have been best worked out. The anthrax bacilli are straight, slightly bent or curved rods, of a comparatively large size, having blunt or square ends and tending to adhere by their extremities so as to form long chains or filaments in the interior of some of which bright granules appear. These granules are spores, which, under certain favourable conditions, are capable of giving rise to the parent bacillary forms. The spores are much more resistant to external and unfavourable circumstances than the bacilli, being specially able to withstand considerable heat and drying. Besides, by the formation of spores, anthrax bacilli can multiply by a process of fission. The chief importance of the connection of anthrax with soil lies in the fact that the disease is specially prevalent in certain countries among animals grazing upon damp soils, rich in humus during the hotter months of the year. The infection of these animals is derived from the presence of anthrax bacilli in or on the soil surface, derived from a previous case of the disease, either from discharges of a diseased animal or from the dead carcass of one which has been either carelessly buried or left to putrefy on the surface. Pasteur suggested that, after the burial of an animal dead from anthrax, development of bacilli into spores can take place in the soil, and that these spores, being swallowed by earth-worms, may in turn be carried to the surface so as to be capable of infecting animals grazing thereon. Owing to anthrax bacilli never forming spores except in the presence of free oxygen and a certain temperature, this suggestion of Pasteur's has been severely criticised, but it is quite probable that there is a sufficient amount of oxygen in the soil pores to bring about sporulation, especially if we remember that not only are animals often opened for examination after death, but also the carcass is, as a rule, dragged along the ground before burial, causing effusion of liquid, crowded with the specific bacilli, into the surface soil.

The remedy for this sequence of events appears to be the immediate burial of the carcasses of animals dying of anthrax, *unopened* and *deeply*, when the bacilli will not only fail to produce spores but be themselves killed by the putrefactive bacteria in the course of a short time. There, however,

remains the danger of a possible infection of the soil from discharges of moribund animals and the subsequent dissemination of the bacilli and their resulting spores over fields by rain or flood. Their access to drinking water in this way is not unknown, accompanied by the infection of human beings as well as of animals.

Calculus.—One of the oldest and most universal theories concerning the causation and prevalence of stone in the bladder, associates its frequency and endemicity in certain parts of the world with the subsoil water—not from any peculiar variations in either its level, or its quantity, but rather from its quality. In so much, the chemical and mineral ingredients of a water depend on the peculiarities of the soil through which it passes, we are justified and driven to entertain the proposition that this disease is, in some way, associated with soils belonging to certain geological formations. The view that certain properties inherent in the drinking water, particularly hardness, were the real cause in the formation of calculus has been brought forward by many observers. While admitting the general strength of the arguments advanced and the imposing array of cases and figures brought forward by writers, we are still unable to ignore the fact that the force of their arguments is much vitiated by the endemic prevalence of calculus in many places, notwithstanding the use of a comparatively pure soft water, free from lime salts ; while, in other parts, where lime exists largely in the water, the disease is either rare or altogether absent.

In India, where the disease is common enough, experience shows that the cause of it cannot be discovered in the hardness of the water. The evidence from China on this point is probably the most marked ; there the disease is extremely frequent, but a Chinaman rarely drinks plain cold water ; the universal beverage is tea, in which the water has been previously boiled and nearly all lime in it precipitated. Again, both in Egypt and Central Africa, no connection seems to exist between the disease and any special quality of the water. Referring to Europe generally, writers testify, particularly from the Alp region, that there are many localities with very hard water and, at the same time, remarkably free from stone ; as well as other places much subject to calculus, but whose water is either drawn from rain cisterns or from lime-free freshets.

Apart from mere questions of water analysis, the more we survey the distribution area of the disease, the more complex does its relation to soil appear. Thus, in support of the view held by some that chalk soils are peculiarly conducive to this affection, we find it to be extensively prevalent on the calcareous and dolomitic soil of the basins of the Don and Volga ; on the chalk soil of eastern English counties ; on the Jurassic limestone of the Swabian Alps ; in the limestone districts of Cremona and Brescia ; and on the Jurassic limestones of Canada ; and the recent limestone of the United States. On the other hand, we find the disease is equally indigenous upon other kinds of soil, such as the basaltic trap and tufoid formations in the Deccan and Mauritius ; on the alluvial soil of Canton ; on the transition rocks in Cheshire and North Wales ; and the carboniferous rocks of Yorkshire, with the clay sand near Ostend and Dunkirk. Not only do we find these discrepancies, but others in the fact that many parts of England, Switzerland, and the West Indian Islands, whose soil belongs to the recent chalk and limestone formations, are relatively, if not quite, exempt from the malady. In the face of these facts, one is forced to think that neither the soil itself nor the qualities which it gives to the water percolating through or issuing from it have any true influence upon either the causation or prevalence of calculous diseases ; but rather, that the real etiological factors

in the affection, so far from being sought for in any exterior influence, whether climatic or telluric, must, on the contrary, be looked for in certain habits of life and nutrition or in congenital and acquired states of individual metabolism.

Cancer.—As the result of various writers', more particularly of Haviland's, inquiries into the geographical distribution of disease in Great Britain, an increased regard has been attached, in recent years, to the part played by telluric and topographical conditions in the etiology of cancer. Haviland, by constructing a series of "disease maps" from an analysis of the statistics available from the Registrar-General's office, stated that cancer shows "an infrequency in places characterised by elevated sites and limestone formations, or even by sites subject to floods, but within the immediate influence of calcareous rocks," but betrays a high mortality in districts "associated with flooded, low-lying, and clayey areas." He cites the Thames valley as a typical cancer district in all respects. Further, by assuming that cancerous diseases are due to a micro-parasite and that since certain pathogenic organisms are inhabitants of the soil, Haviland is of opinion that there is a probability that the organisms concerned in cancer production also exist in the soil, thriving more especially in the alluvial earth. Subsequently, D'Arcy Power endeavoured to favour the production of carcinoma in animals by exposing them in various ways to the influence of soil seeded with minced cancerous tissues. He employed a soil which fulfilled all the conditions required by Haviland for the successful propagation of cancer, assuming, for the sake of experiment, that the cancer germ existed, and that a part of its life was passed in earth. His results were entirely negative, both as to the propagation of cancer from cancer, and as to the probability of the soil having anything at all to do with its etiology.

In the light of modern research as to the nature and propagation of cancer, we are forced to conclude that there is practically no evidence to show either that soil plays any active part in the production and dissemination of malignant disease, or that there is any real connection between soil conditions and cancer prevalence.

Cholera.—The earliest writers upon this disease emphasised its remarkable preference for particular places; while the history of each successive epidemic implies, besides an importation of the contagium, certain local conditions which may be either general sanitary defects or peculiarities of climate and soil. It is now very generally accepted that the particulate contagium of cholera is the specific micro-organism called the comma bacillus. Its morphological and biological characters are sufficiently distinct to render its differentiation easy. Whether it is by this particular organism *alone*, or whether it is only when in conjunction with some other, as yet unknown, microbe that the symptoms of cholera are generated, the general belief prevails that cholera, in this country at least, is mainly spread by means of the drinking water, though dissemination may occur in other ways, more particularly from an "excrement-sodden earth" which fouls not only water but air. On the Continent, especially in Germany, much importance has been attached to movements of the ground water in the diffusion of cholera. This was due to the teachings of Pettenkofer, who maintained that cholera never prevails, as an epidemic, where the soil is impermeable to water, or where the soil water does not violently fluctuate in level. Pettenkofer admitted the presence of a specific germ in the soil, which he considered is only able to virulently manifest itself when the soil has been rendered suitable, as when the ground water, after having risen to a higher level than usual, begins to fall again. This sequence of

events is quite conceivable, by either the assumption that the sudden rise and fall in ground water-level carries into wells some organic cholera-producing matter from the soil, which otherwise could not gain access to water-supplies; or by assuming that the cholera micro-organism, if present in the upper soil layers, is merely awakened into activity by warmth and moisture, and subsequently becomes diffused into the atmosphere, as a drying zone of soil forms on the fall of the soil water. The later utterances of Pettenkofer emphasised this latter view, for he says, the rise and fall of ground water are but an "index of the humidity or moisture of the porous and permeable soil which overlies the ground water."

Although these views as to the connection between cholera outbreaks and variations in soil heat and levels of soil water have not received much confirmation in England, still Lewis and Cunningham's observations, in Calcutta, indicate some inverse relation between conditions of water-level and cholera prevalence. The level of the ground water in Calcutta is highest in September (minimum of disease), lowest in May (maximum of disease), and therefore accords closely with the inverse relation affirmed by Pettenkofer. On the other hand, no such relation was found between the cholera curve and those of soil temperature, and of the amount of carbon dioxide in soil air.

It has been alleged that (for India at least) no widespread epidemic of cholera can occur unless during or after rain. This can be readily understood as the rain merely washes the specific germ and cholera material out of the soil into wells, rivers or other common sources of water-supply. On the other hand, excessive rain will often tend to arrest the disease, however high the temperature may be, owing chiefly to the micro-organisms being carried further from the surface, where they are no longer able to gain access to water-supplies.

It is readily intelligible, from these considerations, that low-lying and crowded districts invariably suffer more severely from cholera, during epidemics, than those at higher levels and more sparsely peopled. The former have usually not only to contend with their own local impurities, but, not infrequently, also with those carried into them by the drainage of ground water from places above them.

It must not be overlooked that, unless these various agreements between cholera curves and curves of soil heat, moisture, and ground water-levels are to be regarded as mere concidences, an essential factor to explain their association with cholera prevalence is the presence in the soil itself of the specific germ. Assuming this to be the vibrio known as the "comma bacillus," it is interesting to find that in no cholera epidemic has this micro-organism been found in, or isolated from, the soil; though cholera commas have been repeatedly demonstrated to be present in sand placed in filters in India. To those familiar with the countless numbers of bacteria present in even comparatively clean soils, and the difficulties experienced in obtaining pure fractional cultures of particular forms from impure growths, this non-isolation from, and failure to find in, soil samples the cholera vibrio will not be surprising. Though this micro-organism has not been found in soil, many observations have been made regarding its behaviour and fate when introduced into soil samples. Experimental facts indicate that choleraic comma bacilli are, under ordinary circumstances, somewhat feeble in the struggle for existence; and when introduced into soil and water, of varying qualities, so long as these retain their natural conditions, they tend to disappear, mainly owing to the influence exerted on the commas by other fungi and schizomycete organisms. Cunningham's experiments, made with garden

humus kept moist under a bell-jar, show a survival of cholera commas for some forty days. If the earth were much fouled, as by mixtures with fæces, the commas were not recoverable later than five to nine days ; if the fæces, before mixture with the soil, were boiled, the commas were found as late as the twenty-sixth day. Dempster's experiments indicate that (1) in dry soils, evaporation not prevented, comma bacilli were alive on the third but dead on the fourth day, in white sand, in yellow sand, and in garden earth ; (2) with a moist soil, evaporation not prevented, they were alive on the seventh day in white sand, and on the thirty-third day both in yellow sand and garden earth ; (3) when evaporation was almost prevented they were alive on the twenty-eighth day in white sand, and on the sixty-eighth day in yellow sand and garden earth ; (4) in dried soil they did not live longer than one or two days ; (5) in white crystal sand, evaporation allowed, the commas were dead on the thirtieth day, the moisture present being 0·66 per cent. ; when evaporation was prevented, they were alive on the hundred and seventy-fourth day, the sand still containing 7·1 per cent. of moisture ; (6) in peat, comma bacilli were invariably dead in twenty-four hours, irrespective of the amount of moisture present. Houston's experimental investigations of inoculation of soil with particular microbes lead him to infer that both the spirillum of cholera and the *Bacillus prodigiosus* rapidly decrease in number in the surface layers of soil ; that the *B. prodigiosus* may retain its vitality there for 158 days ; but Koch's vibrio dies quickly or becomes so reduced in number as to be no longer capable of being demonstrated. This occurs to the vibrio in a few days in "undressed" soils ; in about twelve days (possibly, however, forty days) in soils periodically watered with liquid manure. The degree of moisture is, therefore, a factor of the greatest importance in regard to the retention of vitality of these organisms in soil, and this may be the explanation in part of the endemic and epidemic prevalence of cholera. In Lower Bengal the soil is always moist, and cholera is endemic, but is lessened during the heavy rains when the soil becomes saturated ; in the Punjab the soil is dry, and epidemics do not occur unless some amount of rain has fallen ; in the one case the rains hinder, in the other they favour the appearance of cholera. The difficulty which comma bacilli appear to have in surviving in such media as earth or water appears to be mainly due to their inability to form spores or otherwise assume a resistant form. It is necessary in this connection, however, to remember that, among the many comma bacilli obtainable from cholera dejecta, there is, in all likelihood, a plurality of species which do not behave uniformly in water, soil, and other media. By a due appreciation of this fact, it is probable that many experimental inconsistencies may be explained ; especially as both Nicati and Reitsch have shown that cholera bacilli are capable of existing three months in such foul water as that of the Port of Marseilles.

The general evidence indicates that the specific bacteria of cholera discharges are capable of a much longer existence in the superficial soil layers than has hitherto been supposed ; and consequently it is specially necessary to guard against pollution of the soil, and through it against the probable contamination of both water and air. In India, all the evidence points to the soil as playing a very large part in the diffusion of cholera, chiefly as affording a nidus in which the comma bacilli can retain their vitality, if not actually multiply, for long periods. The soils in which this sequence of events seems particularly to occur, are the loose and partially moist sands in the beds of rivers, and along the sides of tanks and other bodies of water used for bathing and laundry purposes. While the connection between

soil conditions and cholera prevalence appears to be true for some localities, particularly its areas of endemic prevalence, the evidence is not sufficiently strong to warrant its universal application; in fact, as will be discussed in a subsequent chapter, the diffusion of the disease is largely dependent upon other factors than soil states.

Diarrhœa.—In especial relation to that peculiar form of diarrhœa which is apt to prevail epidemically in summer and autumn, a considerable amount of evidence has been brought forward of late years to associate its connection with life processes of micro-organisms present in the superficial soil layers, but as yet not satisfactorily isolated. It is of very general knowledge that diarrhœa mortality is low in places built upon solid rock, but high where the soil is porous and loose, also upon sand or a thick surface mould. Gravel or coarse sand varies in its relation to the disease mortality and prevalence in proportion as the loose elements or stones vary. The more gravel approaches to sand in its fineness, or to rock in its coarseness, so its relation to diarrhœa appears to be greater or less. Clay soils do not appear to be, in themselves, specially favourable to a high diarrhœal mortality. The marls are either favourable or unfavourable to diarrhœal prevalence in proportion as they are loose and permeable on the one hand, or plastic and stiff on the other.

Ballard, who was one of the first to indicate any possible connection between soil states and diarrhœa in this country, thinks that the presence of much organic pollution renders a soil distinctly more favourable to a high diarrhœa mortality than it might otherwise be; such organic fouling need not be of a fæcal or excremental nature. For these reasons, diarrhœal mortality and prevalence are apt to be high where dwellings are built upon made ground, upon the refuse of towns, upon reclaimed areas, or upon the sites of old market gardens, and in places where the earth beneath and around is polluted by collections of liquid filth in cesspits, or where sewage has soaked into it from imperfect drains, or from the surface of the ground. It is the opportunities for the collection of organic filth in the fissures of certain kinds of rocks that seem to impart to them, when built upon, a tendency to cause diarrhœa. In discussing the influence of moisture of a soil, Ballard remarks that excessive wetness and complete dryness of soil appear to be both unfavourable to diarrhœa prevalence. The degree of habitual moisture, specially favourable, is that amount which, while being marked, is not sufficient to preclude the free admission of air between the constituent physical elements of the soil. Such a degree of dampness occurs when the subsoil water stands sufficiently near the surface to maintain by capillary attraction the dampness brought about by previously greater nearness of the water to the surface; or when the soil, as in the case of marls, contains sufficient of the clayey element to imprison some of the water saturating it at some time previously. The requisite degree of soil dampness may be produced by floods, or from habitual surface soakage, as from leakage of conduits, sewers, and drains.

One of the most important soil conditions indicated by Ballard, as influencing the prevalence of diarrhœa in England, was the temperature of the soil. As the result of many years of observation, regarding the relationship between diarrhœa prevalence and the earth temperature at depths of 1 foot and 4 feet from the surface, he says that "the summer rise of diarrhœal mortality does not commence until the mean temperature recorded by the 4-foot earth thermometer has attained somewhere about 56° F., no matter what may have been the temperature previously attained by the atmosphere or recorded by the 1-foot earth thermometer." The maximum mortality

from diarrhœa appears not to occur until quite a week after the 4-foot thermometer attains its maximum mean, and declines gradually with the decline of the temperature recorded by the same thermometer. The heat of the atmosphere and of the more superficial soil layers appear to exert but a subsidiary influence upon diarrhœa prevalence.*

Very similar results were obtained by Tomkins,† who, at Leicester, for several years recorded the temperature of the soil at 1-foot and 4-feet levels during the warmer months. His observations showed that it is not till the heat of the earth at a depth of 1 foot has reached 60° F., and remains some 4° lower than this at 4 feet, that diarrhœa begins to prevail to any marked extent. Tomkins, however, was disposed to regard the 1-foot temperature as the more significant.

Speaking generally, both Ballard and Tomkins express a belief that epidemic diarrhœa, as observed in England, is due to a soil-bred organism, which, at times, escaping from the earth becomes air-borne, and thence gains access to the human body by food or drink. This organism has not been isolated so far, neither is there any definite evidence forthcoming from either the Continent or the tropics which causally connects epidemic diarrhœa with soil conditions. We are only too well aware that fermenting and decomposing food, especially milk, may cause diarrhœa, and that, since these processes are mainly the result of bacterial action, these latter may be regarded as the fundamental causes of the disease. But it is open to doubt whether sufficient evidence exists to show that these organisms ordinarily reside in, or are at all dependent upon conditions of, the soil, to permit our forming a working hypothesis upon these lines.

Newsholme's studies on epidemic diarrhœa show that the fundamental condition favouring this disease is an unclean surface soil, the particulate poison from which infects the air and is swallowed most commonly with food, especially milk.‡

Diphtheria.—All accounts of diphtheria show a tendency on the part of this disease to recur in the same districts year after year. The question naturally suggests itself, are the reappearances due to a revival of the contagium derived from previous outbreaks in the same place, or to some favouring condition which the place offers for the development of infection derived from some other quarter; and have these favouring conditions any dependence upon the character and state of the soil? As far back as 1858, Greenhow reported to the Medical Department of the Privy Council that diphtheria was especially prevalent on cold, wet soils. Later, in 1881, Airy describes the localities affected as "for the most part cold, wet clay lands," but he adds, "there is evidently great variety in the soils on which diphtheria can prevail, for it is found in full force on the chalk downs of Kent, on the loamy sands and clays of the Sussex weald, on the alluvium and boulder clay of Essex, on the marls of the new red sandstone, and on the slopes of the slate rocks of Wales."

An analysis of the innumerable reports upon outbreaks of diphtheria in various parts of Europe indicates that the geological features of the affected districts appear to play a less important part in the incidence of the disease than does soil dampness. This is especially well shown by Kelly § and Barnes in their accounts of the epidemics occurring in Sussex and the Eastern counties respectively. The figures given by the latter show the relative

* Ballard: Supp. to Report of Med. Off. to Loc. Gov. Board, 1888.

† Tomkins: *Brit. Med. Journal*, 1889, vol. ii. p. 180.

‡ Newsholme: "A Contribution to the Spread of Epidemic Diarrhœa," *Public Health*, 1899.

§ Kelly: *Proc. Brit. Med. Assoc.*, 1886.

proportion of outbreaks to inhabitants as being 1 in 1800 on dry soil, and 1 in 300 on wet.*

A very interesting series of facts dealing with the inter-relationship between diphtheria prevalence at Maidstone and movements of the subsoil water are given by Adams.† His observations, extending over nine years, show that a strict concordance may be traced between soil dampness and diphtheria on the one hand, and absence of diphtheria and soil dryness on the other. But the dampness and dryness of the soil depend upon the rise and fall of the ground water and have their appropriate seasons; so long as the order of this occurrence is preserved, health is maintained. As long as the soil is well washed by the winter's high tide and afterwards dried and aerated during the summer's low tide, all goes well; but so soon as these salutary movements are arrested or their order disturbed, diphtheria prevails, reaching its acme of prevalence when stagnation at a relatively high level is most complete. For the conception of this relationship between the movements of the subsoil water and the prevalence of diphtheria, it is assumed that the germ of the disorder resides in or upon the soil, and is liable to be displaced and dispersed along with the subsoil air. Adams maintains that the two chief agencies concerned in the discharge of the soil air into the atmosphere we breathe are reduction of atmospheric pressure, which acts by aspiration, and rainfall, which operates by compression. Probably the latter is by far the more effectual, though both may often act in concert.

Newsholme's researches on the origin and spread of diphtheria caused him to conclude that an epidemic of diphtheria never originated in towns and countries when there had been a series of years in which each year's rainfall was above the average amount.‡ The greatest and most extensive epidemics occurred when there had been four or five consecutive dry years. Dry years imply low ground water, and in the years of epidemic diphtheria the ground water is exceptionally low.

In connection with the foregoing generalisations, it is interesting to note the actual behaviour of the diphtheritic contagium in soil. The true bacillus of diphtheria is now recognised to be that first described by Löffler; but we have no actual proof that this micro-organism is either an ordinary or even occasional resident of the soil, or that it becomes air-borne in sewer gas or soil emanations. Experiments show that pure cultures of this bacillus, when mixed with garden soil, constantly moistened short of saturation and kept in the dark at a temperature of 14° C., will retain their vitality for more than ten months. They die out from moist soil, kept at 26° C., in about two months; from moist soil at 30° C., in seventeen days, and from dry soil at the same temperature within the week. False membranes from cases of diphtheria, when placed in soil under similar conditions, appear to retain their specific infectivity for slightly shorter periods. In the laboratory, absolute soil dryness is as distinctly antagonistic to the vitality of the diphtheritic bacillus as soil dampness is favourable.

These experimental results explain to a large degree the general absence of diphtheria throughout the plains of India, and its endemic prevalence in the Indian hill stations and Europe generally. The peculiar connection of subsoil water-levels with diphtheria prevalence, as emphasised by the experience of Maidstone, is to be largely explained by the influence which they have upon the greater or less degree of soil dampness. Both

* Barnes: *Brit. Med. Journal*, 1888, vol. ii. p. 331.

† Adams: "On the Relationship between Diphtheria and Movements of the Ground Water." *Proc. 8th Internat. Cong. of Hyg. and Demography*, Buda-Pesth, 1894.

‡ Newsholme: *Epidemic Diphtheria*, Lond. 1898.

statistically and experimentally, we find that a damp soil favours the life and development of the diphtheria bacillus; while prolonged submersion and drought kill it. In the incidence of epidemic diphtheria, we are justified in regarding, in country places at least, constant soil moisture as a chief factor; while possibly, in the case of urban outbreaks, mere soil dampness is subsidiary to other more potent causes.

Dysentery.—Owing to its endemicity, if not epidemic diffusion in certain places, often within narrow limits, earlier writers on this disease were disposed to consider certain states of the soil of special importance in its production. A glance at the literature of its wide geographic distribution shows that dysentery can prevail independently of elevation and ground configuration, but this conclusion is much vitiated by the transparent manner in which all older writers have included and at times made interchangeable with this disease, all forms of diarrhœa and not a few fevers. When we look into details, and rigidly adhere to the question of the presence or absence of true dysentery, we find that, in both tropical and sub-tropical latitudes, the disease tends to prevail most on low-lying damp lands presenting much decay of animal and vegetable matter.

We know that under the name of dysentery are embraced two distinct pathological entities, namely, amœbic and bacillary dysentery. Although there is still much to be learnt regarding the life history of both the etiological agents, still sufficient is known to justify the belief that an amœba and a specific bacillus are the respective causes of these two varieties of the disease known clinically as dysentery. There is practically no evidence to show that either the amœba of endemic dysentery or the bacillus of epidemic dysentery has any special predilection for the soil; on the contrary, the few observations which have been made in respect of the bacillus indicate that its viability on or in soil does not exceed twenty-one days. How long the amœba of dysentery can survive in soil we do not know; analogy suggests a very short period. Apart from this, it is notorious that dysentery tends to prevail particularly during war and among aggregations of men under general insanitary conditions, such as faulty disposal of effete matter, local fouling of the ground surface, and the drinking of dirty or impure water. The latter probably plays the largest part in the causation and spread of dysentery, the influence of soil being quite secondary, and that only as affording a temporary nidus for the specific organisms, whether amœbic or bacillary, which gain access to man's food or drink by being blown or detached as dust from the soil surface.

Enteric Fever.—The evidence which has been advanced in favour of connection between this disease and soil is very similar to that which has been discussed in special reference to cholera and diphtheria. Pettenkofer's* observations on the wells of Munich led Buhl to the discovery that in that city there is a very close relation between the height of the ground water and the prevalence of enteric fever; the outbreaks of enteric fever occurring when the soil water was lowest, and especially when, after having risen to an unusual height, it had rapidly fallen. The observations have been further extended by Pettenkofer with the same results, but in this country the connection has not been traced.

Criticising these views of Pettenkofer's, Ranke has pointed out that no enteric fever exists in the neighbourhood of Munich but what is imported from Munich itself, although both the soil and ground water are the same. Munich has a soil consisting of fine sand, with a peculiar power of holding

* Pettenkofer: *Die Boden und sein Zusammenhang mit der Gesundheit des Menschen.* Berlin, 1882.

nitrogenous substances; it is largely honeycombed with cesspools, from which more than 90 per cent. of the contents soak into the surrounding soil, and, as the streets are well paved, the houses of the town constitute the only outlets for the foul soil air. A very similar argument, together with some very interesting facts concerning the prevalence in Dublin of enteric fever, have been brought forward by Sir. C. A. Cameron.* For some years a persistent occurrence of this disease has existed in Dublin, which cannot be accounted for either by polluted water, milk, or food, and which has not very sensibly decreased even after an improvement in the water-supply. Sir C. A. Cameron attributes this prevalence to the practice, which has been in use in Dublin for years, of storing excreta in pits, so that the soil has become thoroughly saturated with the specific organisms of the disease; these, he thinks, are carried into the atmosphere by displacements of ground air. According to him, the ratio of cases to population, living in Dublin, on a loose porous gravel soil for the ten years 1881–91, was 1 in 94; while the ratio for those living on stiff clay was but 1 in 145. "This is what we should expect, since the movements of the ground air are much greater in loose porous than in stiff clay soils."

No pronounced relation has been found between the death-rate or prevalence of enteric fever and the temperature or putrefactive activity of the soil.

Assuming that there is some connection between oscillations of the ground water or movements of the ground air and enteric fever, it is necessary to realise the entrance and existence within the soil of a specific germ. This is now accepted as being the Eberth-Gaffky bacillus. Many observations have been made which show the possibility of this micro-organism existing for considerable periods of time under certain conditions of warmth and moisture. Robertson has shown that the *B. typhosus* can grow very easily in certain soils, and persist through the winter months when the soil is artificially fed, which may be effected by a leaking drain or by the access of filthy water from the surface; the micro-organism will then take on fresh growth in the warm season. Cultures of *B. typhosus* planted at a depth of eighteen inches were found to grow to the surface.

Martin's † experiments on the growth of the typhoid bacillus in soil brought out the following facts:—

1. "That the soils which are favourable to the growth of the typhoid bacillus are those which have been cultivated, more particularly soils of gardens and the entourage of houses. In these soils the bacillus was found alive after 456 days; this being true for sterilised soil which was moistened throughout with water. On drying this soil, even when it had become so dry that it could be made into a fine powder, the typhoid bacillus could still be obtained from it and had retained its vegetative properties, although it grew more slowly than when obtained from the same soil in its moist condition."

2. "Virgin soils, sandy or peaty, when sterilised and containing no matter what portion of water, are absolutely inimical to the growth of the typhoid bacillus."

3. "In favourable soils in a moist condition, the bacillus not only grew at a temperature of 37° C., but it flourished when the soil was exposed to temperatures between 3° and 16° C." The bacillus not only grew on the surface but extended in the depth of favourable soils.

* Cameron: *Trans. Roy. Acad. Med. in Ireland*, vol. vi., 1888.

† Martin: "On the Growth of the Typhoid Bacillus in Soil," *Supp. Med. Off. Rep. Loc. Gov. Board*, 1896–7, 1897–8, and 1898–9.

4. "The growth of the typhoid bacillus in soil in the presence of other bacteria is clearly the subject most important to be considered from the point of view of the conditions occurring in nature." In one experiment the *B. typhosus* appeared to live for fifty days in the presence of other bacteria. Later investigations on the growth of the *B. typhosus* in unsterilised soil showed a marked contrast between the growth of this organism in sterilised and unsterilised soil. Only once was the *B. typhosus* recovered from unsterilised soil to which it had been added, and that was not later than twenty-four hours after the addition. The bacillus disappeared, whether the soil was kept at the temperature of an outside shed, at the temperature of the laboratory, or at a uniform temperature of 37° C.

Firth and Horrocks * re-investigated this question as to the viability of the enteric bacillus in soil under varying conditions and found that, (1) there is no evidence to show that this micro-organism displays any disposition or ability to either increase in numbers or grow upwards, downwards or laterally in soil. (2) That the enteric bacillus in able to assume a vegetative existence in ordinary and sewage-polluted soil and survive therein for varying periods, amounting in some cases to as much as seventy-four days. (3) That the presence or absence of organic nutritive material in the soil appears to be a largely negligible factor, since the enteric bacillus can survive indifferently well, whether it be an organically polluted soil or a virgin soil, and whether it receive dilute sewage or merely rain-water. (4) That in fine dry sand the enteric bacillus survives some twenty-four days, but that from similar sand kept moist with either rain or dilute sewage the organism disappears about the twelfth day, probably being washed down into the deeper sand layers by the liquids added. (5) That in peat, the enteric bacillus rapidly dies out, not surviving more than thirteen days. (6) That from soil, allowed after inoculation to become so dry as to be readily blown about as dust, the enteric bacillus can be recovered up to the twenty-fifth day. (7) That in a sewage-polluted soil, recovered from beneath a broken drain, the enteric bacillus was able to survive for sixty-five days, and that in ordinary soil moistened occasionally with dilute sterile sewage the micro-organism was recoverable up to the seventy-fourth day. (8) That the enteric bacillus is able to survive in surface soil an exposure to 122 hours of direct sunshine, extending over a period of twenty-one consecutive days, the locality being Hampshire, England, and the season the months of June–July. In regard to this last observation it is interesting to note that Aldridge,† working in India, recovered the enteric bacillus from earth, fouled by the urine of patients suffering from typhoid bacilluria, on the first, fourth, and ninth days of drying. In his experiment he refreshed the soil with the infected urine on three successive days. In the same country, W. S. and L. W. Harrison ‡ found that enteric bacilli survived in dust contaminated with infected urine for five days, and in the same dust exposed to the June sun of India for nearly three days; during seventeen hours of which the dust had been exposed, as indicated by a buried thermometer, to a temperature of 53° C.

Although a vast amount of evidence has accumulated, which indicates the specific contamination of food and drink as the most frequent channel of infection for enteric fever, still it must not be overlooked that dried enteric excreta, particularly when buried superficially in dry sandy soil, may be carried by the air and distributed as dust upon food. This is a point of

* Firth and Horrocks: *Brit. Med. Journal*, September 27, 1902, p. 936.

† Aldridge: *Ind. Med. Gaz.*, July 1903.

‡ W. S. and L. W. Harrison: *Journ. Roy. Army Med. Corps*, vol. ii. p. 721.

importance in connection with the maintenance and management of the dry earth-closet system in hot countries like India; where possibly it is a not infrequent way in which enteric fever is spread. Copeman * quotes a curious case from Von Giett, which illustrates how the soil may constitute a nidus, in which the enteric germ may lie dormant for an indefinite period. "A man who had acquired enteric fever elsewhere brought it to a village. His evacuations were buried in a dung-heap. Some weeks later five persons engaged in removing some of the dung were attacked by the disease; their discharges were sunk deep in the heap. At the end of nine months, it was completely cleared out by two workmen, one of whom fell ill of enteric fever and died."

Notwithstanding the discordance of the facts noted from various localities in reference to the connection between the action of either ground water or air and enteric fever prevalence, a few authenticated cases, like the foregoing, taken in conjunction with results of laboratory experiments, which show the possibility of the specific bacilli being able to remain alive some time in earth, make it difficult to deny the importance of the soil as a possible breeding-place of the enteric germ.

Goitre.—The view that some causal connection exists between this disease and soil is based upon the marked influence which locality bears to its endemic prevalence, coupled with the fact that healthy persons, coming into goitrous places from non-goitrous localities, not unfrequently contract the disease after a longer or shorter stay; while, on the other hand, removal from goitrous centres has been found to be one of the most certain means of either overcoming the disease or preventing its further development.

The general area of distribution of goitre shows that the disease is very largely, though not exclusively, endemic in mountainous districts. The observations, that in these endemic mountainous districts the disease prevailed the most in the deeply cleft valleys receiving little sunshine and wind, and possessing a damp or marshy soil, gave rise to a generally current belief that a wet soil had some peculiar influence upon its causation. Though it is true the disease does largely prevail in valleys and on damp, wet soils, still from its frequent occurrence in wide and open valleys and on plains which are dry, this wet soil, the degree of elevation or the configuration of the ground, cannot be seriously regarded as etiological factors.

As to whether any connection exists between the endemic occurrence of goitre and soil mineral constituents has been a question hotly argued by many writers; particularly by those who regard its cause to lie in the habitual use of water containing certain substances, such as calcic carbonate, magnesia, or even metallic sulphides. Inasmuch as the presence of these minerals in the water depends on the ground from which it springs or over which it flows, it is natural to conjecture that goitre must be associated in its endemic form with limestone, dolomite, or metalliferous soils. This magneso-limestone soil theory of the origin of goitre has been much criticised, notably owing to the fact that although in New Zealand the greater part of the native population live upon the magnesian limestone, goitre and cretinism are entirely unknown among them. Saint Lager advanced the view that goitre is only endemic in regions with metal-yielding rocks, and that its occurrence depends essentially upon the presence of iron and copper pyrites, and that its prevalence on soils containing magnesia is explicable by the fact that such soil is particularly liable to contain those metallic sulphides. This view has lately found support in the inquiries of Lebour

* Copeman: Article on "Soil" in Stevenson and Murphy's *Treatise on Hygiène*, vol. i. 1892.

on the distribution of goitre in England. Unfortunately for the full acceptance of these views, in the very districts of France in which iron sulphides occur in the largest quantity, endemic goitre is conspicuous by its absence, while the disease is endemic in many parts of that country where not a trace of any metal can be discovered in the soil.

The more recent observations made by McCarrison * on the distribution of goitre in Chitral, Gilgit and Nagar indicate that the most goitrous villages were associated invariably with limestone outcrops, and that the water-supply was the probable vehicle of the spread of the disease. The disease-producing element in the water appears to be matter in suspension, but whether this be inorganic or some form of microbial life is uncertain. The striking case of the importation of the disease into Nagar, which McCarrison explains as being due to the contamination of a certain spring by a goitrous family who had migrated recently from a neighbouring State, certainly suggests the introduction of a micro-organism into a suitable water-supply; but, until that micro-organism is isolated and the chain of evidence against it more complete, we are not justified in dogmatising upon the matter. At present, the most we can assert is the undoubted preference of this affection to prevail in mountainous districts where the water-supply arises in or flows over and through limestone formations, and the remarkable immunity from goitre of those who, living in these areas, consume only rain-water. The problem of the true causation of goitre must be still regarded as awaiting solution. It is possibly a micro-organism present in certain soils and conveyed to man by means of water.

Lead-poisoning.—It is well known that some drinking waters drawn from certain areas have a remarkable capacity for dissolving lead from the pipes by which they are distributed. These waters are commonly obtained from moorlands or high gathering grounds where peat is more or less plentiful; they are characterised by an acid reaction, while the non-lead-solving waters are, on the other hand, neutral or faintly alkaline. Knowing the richness of peaty soils in complex acids, described under the names of crenic, ulmic, humic, and apocrenic acids, it is believed that the source of the acid, found to be present in lead-solving waters, is the soil through and from which the water is gathered. Unfortunately, very little is known of this water acidity, as the amount is always small; but the actual acid found in the water of the service pipes is not invariably the same as that to which the acidity on the gathering grounds is due, some chemical decomposition apparently taking place as it passes through the mains. Some have suggested the acid to be sulphuric acid, produced by the oxidation of iron pyrites in the shale, so frequently found under peat beds; in support of this view the evidence is not strong, while in favour of the opinion that it is one of the earth acids may be mentioned that, where peat is most abundant, the acidity is greatest. Evidence is slowly accumulating which is very suggestive of the acid being a product due to the growth of micro-organisms in soil or water. That such might be the case was suggested by Power † in 1887, since which date experiments have been made by Houston,‡ which are confirmative of the belief that some micro-organisms are obtainable from peaty soils, whose growth is accompanied by the formation of an acid, capable of dissolving lead. Further observations are, however, required before the subject can be considered to be properly understood.

* McCarrison: "Proc. Royal Medical and Chirurgical Society," *Lancet*, 1906, vol. i. p. 1110; *also* "Further Observations on Endemic Goitre," *Lancet*, 1906, vol. ii. p. 1570.

† Power: Supp. to 16th and 23rd Report Local Government Board.

‡ Houston: Supp. to 27th and 30th Report Local Government Board.

Malaria.—There is no evidence to show that malaria is caused by any mineral constituents of the ground, more particularly as it prevails upon soils of such widely different composition and origin as alluvial, sandy or ferruginous earths, as well as upon soils formed from the weathering of metamorphic rocks. Whether a given soil or tract of land is malarious or not depends essentially upon how far it affords facilities for the lodgment of surface water wherein mosquitoes can breed ; for this reason low-lying land covered with rank vegetation and estuarial marshes are common localities for the prevalence of the various forms of malarial fever. Their permanent flooding with deep water or complete drainage will, as a rule, render them non-malarious.

Malignant Œdema.—This is a fatal disease of mice, guinea-pigs, and rabbits. In man it is commonly spoken of as progressive gangrenous emphysema, being chiefly observed after compound fractures or wounds, and characterised by a rapidly spreading œdema in which the subcutaneous tissues, commencing at or near the injury, get distended with a clear reddish fluid containing bubbles of gas. The frequency of this affection following injuries or wounds into which earth had passed or come into contact, early drew attention to the connection between it and soil. Its infective agent is now known to be a bacillus morphologically similar to that of anthrax, but differing from it in being anaerobic. The œdema bacillus appears to be widely distributed, being found in the most varied putrid substances, in the bodies of decomposing animals, in fæces, and in every specimen of earth which has been impregnated with putrefying matter. These bacilli are particularly found in garden earth, after recent manuring, where they appear to be able to pass through their characteristic cycle of development as saprophytes.

Plague.—Recent observations have shown that soil, under certain conditions, may contain the infective agent of plague. Although the existence of the plague bacillus in earth cannot be doubted, this connection between the two cannot be attributed to any special mineral or physical features of the soil ; all the evidence goes to show that it is only the soil of rooms in which plague cases have existed, or in which plague-infected rats have either died or had their burrows, that is likely to become infected. Only in this limited sense are we disposed to regard there being any real connection between soil or earth and plague prevalence. Very little is known regarding the viability of the plague bacillus in soil, but the few observations that have been made are suggestive that it is dependent largely on the amount of moisture and the temperature. When the soil is dry and the air temperature above 20° C., the bacillus does not appear to live longer than seven days ; but when the soil is moist and the temperature of the air below 16° C., it seems possible that the bacillus may survive for several weeks.*

Phthisis.—In some way which is not clear, a moist soil produces an unfavourable effect on the lungs ; at least, in a number of English towns which have been sewered, and in which the ground has been rendered much drier, Buchanan † showed that there had been a diminution in the number of deaths from phthisis. Bowditch of Boston, U.S.A., and Middleton of Salisbury, noticed the same fact some years previously. Buchanan's evidence was very strong as to the fact of the connection, but the nature of the link between the two conditions of drying of soil and lessening of certain pulmonary diseases is unknown.

* Report Indian Plague Commission, 1899-1900.

† Buchanan : Supp. to 9th and 10th Reports Med. Off. Privy Council, 1866-7.

The importance of these observations appeared to be so great that Buchanan was directed by the Privy Council to make a special investigation in the three south-eastern counties, Surrey, Kent, and Sussex, for the purpose of determining whether any relation could be traced between the prevalence of consumption and the state of the soil as regards moisture. In instituting this comparison, Buchanan classified the several districts as having mainly soils *permeable* by moisture, or soils of such a character that water was unable to escape from them, so that they might be called *retentive*.

An exact comparison between retentive and permeable soils in regard to the prevalence of phthisis was afforded by a limited area, the Wealden, which in part is formed by the Weald clay, in part by the Hastings beds of alternate sands and clays. There are, indeed, no districts wholly of sand to contrast with others wholly of clay; but there are great differences in the proportion of the two soils in different districts. How closely these correspond with differences in the consumption death-rate appears from the following table, in which the districts are arranged in order of the death-rate from phthisis, those being placed highest in which it is least. Where there are gravels over the Weald clay, the figure is divided between the last two columns, it being presumed that they occupy an intermediate position.

District in Order of Phthisis Death-rate.	Percentage of Population Resident on						Total on	
	Higher Beds, mostly Lower Greensand.		Weald Clays.		Hastings Beds.		Sands and Half Gravels over Weald Clay.	Clays and Half Gravels over Weald Clay.
	Sands.	Clays.	With Gravel.	Without Gravel.	Sands.	Clays.		
Hastings	—		—	—	95	5	95	5
Cranbrook	—	—	1	6	84	9	84	16
{ East Grinstead	—	—	—	12	82	6	82	18
{ Tunbridge	—	1	24	7	64	4	76	24
{ Hambledon	49	—	20	31	—	—	59	41
{ Battle	—	—	—	—	80	20	80	20
{ Rye	—	4	—	—	79	17	79	21
{ Maidstone	43	1	45	11	—	—	66	24
{ Cuckfield	21	1	—	25	48	5	69	31
Uckfield	—	—	—	1	82	17	82	18
{ Hailsham	—	—	—	34	61	4	61	38
{ Ticehurst	—	—	—	—	67	33	67	33
Tenterden	—	—	—	29	42	29	42	58
Horsham	—	—	—	56	44	—	44	56
Petworth	30	—	—	70	—	—	30	70

Buchanan's conclusions have been subjected to much criticism, notably by Kelly,* the Medical Officer of Health for East Sussex, who has expressed doubts of there being any intimate relation between dampness of the soil and phthisis. He finds that in the years 1861–70, the order in which the several districts have to be placed in regard to their death-rates from phthisis is different from that given by Buchanan for 1851–60. He points out that most of the impervious beds are to the north of the South Downs, and that consumption seems most common in places which are bleak and exposed as well as damp. He insists on the fact that in West Sussex (as, indeed, throughout England and Wales) there has been of late years a great decrease in the mortality from consumption, although there has been no change in the drainage of Sussex. Kelly is inclined to attribute it mainly to the progress which has taken place in the social state of the rural popula-

* Kelly: *Proceedings Brit. Med. Assoc.*, 1886.

tion. These more recent inquiries, when contrasted with Buchanan's earlier ones for the same localities, do not so much indicate the earlier conclusions to be wrong, as that all varieties of soil being now equally healthy, the cause of the phthisis which still occurs has to be sought for in other directions than soil dampness.

It is probable that dampness is merely one of the many factors which are concerned in causing a predisposition to phthisis. On low-lying, damp soils, colds and catarrhs are notoriously more common than on high and dry situations, and the tubercle bacillus, which is the exciting cause of phthisis, finds a favourable nidus in these cases. We have no reason to think that soil in any particular condition affords a more favourable medium for the preservation of the bacillus than do other materials. Even admitting that soil dampness may favour the prevalence of phthisis by tending to lessen the resistance of the individual to the specific bacillus, it is obvious that many other conditions, such as overcrowding, poverty, ill-feeding, and general neglect of children, may all equally exercise a powerful influence on phthisis mortality.

Rheumatism.—In respect of soil influences it is necessary to make a distinction between chronic rheumatism and acute rheumatism or rheumatic fever. It is well known that the chronic rheumatic diseases prevail most in deep and damp valleys, along sea-coasts, the shores of rivers, and in places which are much exposed to wind. Whatever connection chronic rheumatism and allied affections may have to soil states is probably only in so far as altitude, configuration, and physical characters of the soil affect the climate of particular places. Of all soil conditions, dampness is that which will be most likely to predispose to chronic rheumatism, because it makes a locality cold; and this is particularly likely to occur on clays in low-lying districts. Beyond this general statement we cannot go.

As relates to acute rheumatism or rheumatic fever, the facts are not so simple. The tendency of modern thought is to regard rheumatic fever as a specific febrile disease dependent upon a specific micro-organism. A study of its epidemic prevalence shows that, at intervals of a few years, rheumatic fever tends to prevail epidemically. These epidemics occur in, or just following, years of sparse rainfall. This produces its effect by its influence in causing a warm and dry subsoil, usually with an exceptionally low ground water. From this point of view, rheumatic fever is essentially a soil disease, having close relationships with erysipelas and other septicæmic diseases. The explanation of the epidemic prevalence of rheumatic fever, as well as erysipelas and puerperal fever, lies in the favouring influence of a dry and warm subsoil on the specific contagia of the three diseases. Whether these contagia are alternately parasitic and saprophytic, or each case implies a fresh infection from the soil, is still doubtful. It is noticeable that the conditions of soil producing rheumatic fever and chronic rheumatism appear to be almost exactly opposed to each other. The seasonal distribution of the two diseases is also dissimilar.

Tetanus.—Formerly, a distinction was made between a traumatic and an idiopathic form of this disease; but at the present time the belief prevails that tetanus only results from traumatic infection. The agent which produces this affection is, like that of malignant œdema, an anaerobic bacillus, frequently present in garden and other soil. Nicolaier was the first to demonstrate that when soil from gardens, roads, or fields was subcutaneously inoculated into guinea-pigs and mice, symptoms identical with tetanus were induced. The researches and experiments of Bassano have demonstrated the wide distribution of the tetanus germ in soil, besides

indicating that neither climate nor meteorological conditions have much influence on the life of this micro-organism. The extensive presence of the tetanus bacilli in soil explains why tetanus is more common after wounds on the hands and feet than on any other part of the body; and why it is more frequent amongst children who play about barefooted than amongst adults. Gardeners and grooms are especially liable to it. The peculiar frequency with which grooms and others, in contact with horses, are attacked with tetanus, has induced Verneuil to think that the disease is of equine origin; and that horse-dung is the most potent source of tetanus dissemination. Verneuil's views are largely supported in France, although negative evidence comes from the New Hebrides to the effect that though horses are unknown, yet tetanus is very common there. In regard to this controversy as to the equine origin of tetanus, Nocard has aptly remarked: "To pretend that the tetanic action of soil is due to the dung of horses, more than to that of oxen or sheep, is to say that tetanus is more frequent in the country than in the towns, where horses are much more numerous, a statement absolutely contrary to the facts." Although we cannot accept the equine theory of the origin of tetanus, we must take care not to err too much the other way and attribute its causation exclusively to soil. We must admit the evidence points to the soil as being the chief medium of conveying infection; still, the tetanus bacillus can exist in or on other articles and places, such as the coat of a horse or other animal, in hay, on a rusty nail, or on surgical and veterinary instruments.

Yellow Fever.—The whole history of yellow fever goes to show that though at one time and another its diffusion has been wide, still its native habitat is much less extensive. The extent of its diffusion indicates an independence of geological origin of soil. On the other hand, the prevalence of the disease along the banks of tropical rivers, and in the low-lying districts of certain tropical seaports and inland towns, suggests that a water-logged soil is a constant concomitant of yellow fever. Viewed in the light of modern knowledge concerning the etiology of this disease and the part which the *Stegomyia fasciata* plays in its dissemination, this connection between yellow fever and damp, low-lying ground is explained. Practically, the relationship between soil and yellow fever is limited to the facts which render any particular area a suitable haunt and breeding-place for mosquitoes, especially that variety which appears to be the vehicular host for the conveyance of the infective germ from one human being to another. Beyond this we need not go, and, as in the case of malaria, much that was formerly obscure is now relatively clear.

CHAPTER X

HABITATIONS, SCHOOLS AND HOSPITALS

THE diseases arising from faulty habitations are in great measure, perhaps entirely, the diseases of impure air. The site may be at fault; and from a moist soil excess of water and organic emanations may pass into the house. Or ventilation may be imperfect, and the exhalations of a crowded population may accumulate; or the excretions may be allowed to remain in or near the house; or a general uncleanliness, from want of water, may cause a persistent contamination of the air. On the other hand, these five following conditions ensure healthy habitations :—

1. A site dry and not malarious, and an aspect which gives light and cheerfulness.
2. A pure supply and proper removal of water; by means of which perfect cleanliness of all parts of the house can be ensured.
3. A system of immediate and perfect sewage removal, which renders it impossible that the air or water shall be contaminated from excreta.
4. A system of ventilation which carries off all respiratory impurities.
5. A condition of house construction which ensures perfect dryness of the foundation, walls, and roof.

In other words, perfect purity and cleanliness of the air are the objects to be attained. This is the fundamental and paramount condition of healthy habitations; and it must override all other conditions. After it has been attained, the architect must engraft on it the other conditions of comfort, convenience, and beauty.

In towns, density of population has a direct influence on the mortality of the inhabitants. This fact is well known, and emphasised in nearly every annual report of health officers. It is not so much the density of population, expressed as so many to the acre or square mile, as it is the degree of crowding in individual tenements, which influences so adversely the health of the community. Back-to-back houses illustrate very clearly the effect of population density, involving, as they do, deficient light and ventilation and imperfect sanitary arrangements. Tatham has shown that at Salford the mortality from all causes, from pulmonary diseases, from phthisis, and from the seven chief zymotic diseases taken together, as well as from diarrhœa alone, increases *pari passu* with the proportion of back-to-back houses. "The more crowded a community, the greater, speaking generally, is the amount of abject want, of filth, of crime, of drunkenness, and of other excesses, the more keen is the competition, and the more feverish and exhausting the conditions of life; moreover, and perhaps more than all, it is in these crowded communities that almost all the most dangerous and unhealthy industries are carried on. It is not so much the aggregation itself, as these other factors which are associated with aggregation, that produce the high mortality of our great towns or other thickly populated areas."

Sites.—In towns and villages, the sites of additional or substituted dwellings are generally fixed irrespective of the advice of any one. In the case of isolated dwellings, however, where selection can be made, adverse conditions in the site may render the best-designed and best-built structure unhealthy. It is therefore desirable to know what to select, or at least understand what to avoid in making a selection. The question involves the following considerations :—

1. The aspect or exposure to wind, light, and air.
2. The ground or soil on which it is proposed to build.
3. The surroundings of the site.

Aspect and shelter have each their bearing on the salubrity and equality of temperature. While the situation should afford a free circulation of air about the dwelling, it is advisable to avoid exposure to a prevailing cold wind, and it may be necessary even to secure shelter from this by means of a belt of trees or some rising ground. But neither aspect nor shelter has an influence so great as the condition of the ground or soil beneath and surrounding the dwelling.

Dryness of site is essential to both these advantages. A damp subsoil for the foundation of a house is known to favour the prevalence of disease, and is, perhaps, one of the most fruitful sources of impurity of air in dwellings. Wherever possible, the soil or ground itself ought to be porous, such as gravel or sand, which allows the water to run freely away, or chalk, which retains but comparatively little moisture, and does not cause dampness to collect about the house. The next best soils on which to build are rocks, such as granites, clay slates, limestones, or sandstones ; nearly all these have a good slope, and are easily drained. The loams and stiff clays are not, as a rule, good soils for building purposes, as, unless well drained, they are apt to hold water ; if, however, adequately drained, these are not necessarily unhealthy. Pure chalk forms a healthy site, being permeable ; but if the chalk be mixed with clay (marl), or be underlaid with clay, it becomes impermeable and damp. If of any thickness and not situated in a hollow, gravel beds make good building sites.

The worst soils are the shallow beds of gravel or sand lying on clay ; these are frequently water-logged and proportionately bad ; the same remark applies to reclaimed lands near the mouths of rivers and the so-called alluvial lands, which consist of soils that are really the deposit or sludge from rivers. Alluvial tracts are almost invariably unhealthy, owing not only to their dampness, but also to the large quantity of organic matter which they contain. These soils and sites are peculiarly liable to produce chronic rheumatism, ague, and various forms of malarial fever, as well as catarrhs and neuralgia.

If the site is artificially made, care must be taken to see that the subsoil is free from organic pollution of any kind. In the low-lying parts of towns and cities, or where the subsoil has been excavated for sand or gravel, the place is used frequently as a tip for rubbish of all kinds until the level is raised to a sufficient height to allow of its being utilised for building purposes. Where "made soils" of this nature are utilised as building sites, they should be asphalted or covered with a layer of concrete or other impermeable material at least 6 inches thick, and extending from one outside wall to the other. This will not only prevent dampness and "ground air" rising from the underlying soil into the house, but it will also prevent any liquid refuse sinking into the ground to pollute the soil beneath. As a rule, cellars under houses add to their healthiness, especially if properly built on an impervious flooring and adequately ventilated.

In all sites it is important to notice the distance of the ground water from the surface. If this water is too near the ground level, the site will be damp; it ought never to be nearer the surface than 8 feet, and, if possible, should be at least 15 or 20 feet below the ground-line. Whenever ground is waterlogged, owing to want of an outlet, whether the soil be an open gravel or dense clay, it will afford a bad site, unless the subsoil water is lowered by drainage to such a sufficient depth as not only to reduce evaporation, but to prevent the rising of moisture up to the cellar floors and the foundations of the dwelling.

There is reason to believe that frequent and sudden changes of water level are specially unhealthy, and where these occur the place will not be a good site.

The most essential points to be sought for in regard to a choice of site for building purposes are as follows :—

1. A moderately elevated spot, so that a fall from the building may be secured in one direction at least, sheltered from the north and east, but not so shut in as to impede the free circulation of air round and over it.

2. The site should, if possible, be upon a porous soil, such as gravel and sand, care being taken to see that the subsoil is sufficiently permeable to secure thorough drainage, either naturally or artificially. When a house *must* be built on a retentive soil great precaution must be taken effectually to drain the subsoil and to obviate the dampness of the site as much as possible by the use of concrete.

3. The ground water should not be nearer the surface than 8 feet, and not subject to either great or sudden fluctuations.

4. The surface soil and subsoil, no matter what their nature, should be clean, and not fouled by either sewage or refuse.

5. The site must also be chosen that sufficient facilities shall be secured for drainage and water-supply.

Construction of Dwellings.—The foundations ought to be sufficiently solid and deep enough in the ground to give firmness to the building. When the ground is soft, or a solid foundation cannot be reached, the walls should be built upon a solid platform of concrete or stone, which should be at least four times as broad as the walls. The bases of the walls themselves should be expanded into what are called *footings*, the lowest course of which should be at least twice the breadth of the wall. The height of the footings ought not to be less than two-thirds of the wall thickness. To prevent moisture from rising up the walls of dwellings, it is now usual to build them on a layer of concrete. In addition to this base of concrete, it is necessary to have a layer of impervious material, *i.e.*, *a damp-proof course* within the wall itself. The proper height at which to insert a damp-proof course in external walls is a few inches above the natural ground line, and in internal walls on a level with the bottom of the concrete. Damp-proof courses are made of different materials. Sometimes a double course of slates bedded in cement is used; sometimes a layer of sheet-lead is placed throughout the whole length of the walls. Perforated stoneware tiles embedded in cement have also been applied to the same purpose; these have the double advantage of not only preventing the uprising of moisture, but they also act as a means of ventilating the spaces between the ground beneath and the joists of the floor.

All dwellings possessing basement floors under the level of the natural surface of the ground should have outside areas or dry passages between the ground and their walls. This can usually be secured by digging away the earth on the outside to below the level of the floor so as to form a dry

area. As an alternative plan to this, a device recommended by the Local Government Board in their Model Bye-laws may be employed; this consists in making the wall hollow, with a cavity of 2½ inches extending from the base of the walls to a height of 6 inches above the ground level, and then inserting two damp-proof courses, one at the bottom of the hollow, and below the floor level, the other at the top of the hollow, and therefore above the outside ground level. By this means the inner wall is quite shut off from the soil. Both these arrangements are shown in Fig. 53.

The materials generally used for the construction of walls of dwelling-houses are bricks, stones, and wood. Bricks are made from three kinds of earth, namely, pure clays, marls, and loams. Pure clay consists chiefly of alumina and silica, marls are clays having a considerable amount of lime in them; while the loams are light and sandy clays. Few bricks are made solely from any one of these earths, but rather from an admixture of all three. Bricks are burnt in kilns or clamps. Kiln-burnt bricks are more uniform in quality than clamp-burnt; the latter have part of the fuel mixed with the clay, and traces of it can be detected in the bricks after they are burnt. A good brick should be regular in shape, well burnt, of a uniform colour, and when struck give a clear metallic ring. So porous are ordinary bricks that both rain and air can be easily driven through them; in fact, so much is this the case that it is desirable in all dwellings that the outer walls should, if of brickwork, be at least a brick and a half thick (14 inches), so that in addition to the bricks there may be in the structure of the wall itself a layer of mortar. Mortar is a compound of one part of lime with three parts of clean, sharp sand made up with fresh water. Sand is added to check shrinkage, either in drying or by absorption of carbonic acid from the air. Bricks are superior to any other material for house walls.

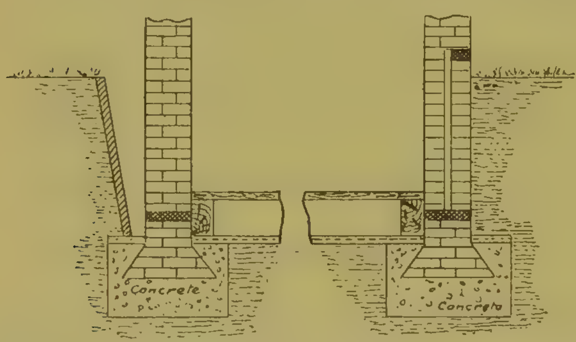


FIG. 53.—DIAGRAM ILLUSTRATING DAMP-PROOF COURSES.

Two kinds of stone are generally used for house building; they are sandstone and limestone. Sandstone has been described as sand made into a cake with clay, lime, and oxide of iron. It is the varying amount of this latter which gives the various colours to it, such as red, yellow, and grey sandstone. Limestone is rock composed mainly of carbonate of lime. Like bricks, stone is both porous and absorbent of water, but in a less degree. During recent years, the use of ferro-concrete has replaced largely the employment of bricks and various stones in the construction of large buildings; the hygienic attributes of this material may be assumed to be similar, though possibly an extended experience may indicate it to possess advantages or disadvantages at present unsuspected.

No woodwork should be placed in a wall except where it is necessary for carrying the floors or roof, or for fixing the fitments of a building, and then it should be so arranged that the shrinking or decay of the wood will not affect the strength of the wall. When the ends of flooring or other timbers are placed in the wall for support, they should rest on stone templates, and space for ventilation should be left all round them: the wall above must not rest upon them.

Wood enters largely into the construction of the inner fittings of all

dwellings. In its natural state it is very absorbent, and the unavoidable cracks and crevices admit both air and water. The chief kinds used are ash, beech, oak, elm, pine, and larch. The first four differ from the latter in being free from turpentine. Good timber should be close and straight-grained, free from cracks and dead knots, and well seasoned.

The walls of all dwelling-houses should be most carefully built from the foundations upwards, whether of brick or stone, with a layer of mortar not only between each course, but under the first course and well fitted into the vertical joints. Bricks are laid in beds or courses, and are usually spoken of as being bonded together.

English bond is the strongest and simplest for all ordinary work. The heading and stretching courses generally alternate, but not necessarily. No bricks in the same course should break joint with each other.

Flemish bond shows headers and stretchers alternately in each course. It is not so strong as English bond, but gives a better appearance, as a smoother face can be shown on both sides.

The thickness of the external walls of dwelling-houses is determined by the size of the building, more particularly by its height. According to the Model Bye-laws of the Local Government Board, the minimum thickness should be as follows :—When a wall is not over 25 feet in height, if it does not exceed 35 feet in length and does not comprise more than two storeys, it shall be 9 inches for its whole height, but if it does comprise more than two storeys or exceed 35 feet in length, it shall be 13½ inches below the topmost storey and 9 inches for the rest. When walls are over 25 feet high and not exceeding 35 feet in length, they should be 13½ inches thick below the first storey and 9 inches for the rest; but if they be longer than 30 feet, then they must be 18 inches thick for the height of one storey, then 13½ inches thick for the rest of the height below the topmost storey, and 9 inches thick for the rest of its height. Walls over 35 feet high must be 18 inches thick for the first two storeys and 13½ inches for the rest. If over 50 feet in height, walls should be 22 inches thick for the height of one storey, then 18 inches for the next two storeys, and finally 13½ for the rest of the height. The interpretation put on this bye-law by many surveyors is often erroneous. The real intention of the Board will be met if, in reading the bye-law, it be borne in mind that the question of storeys only applies when they are in contact with the wall.

Walls built of cut stone need be no thicker than those of brick, but if of rough stone or flint and boulders, they should be at least one-third thicker. Walls made of both brick and stone are not uncommon; the chief point about them is the need of careful bonding together of the two elements. Occasionally walls are made of concrete either rammed down in layers or else built of concrete blocks well cemented together. Wood is at times used in making the upper part of the outer walls of houses; when so employed, it needs to be backed with at least 4½ inches of brickwork and well bonded together.

Owing to the absorbent and porous nature of all these materials, special care must be taken that outer walls constructed of them do not admit damp, especially when in positions much exposed to rain and wind. Different means are adopted for resisting the effects of driving rain; in some parts, vertical slating of the external walls is used, while in othes places plain tiles are substituted, and present a much more agreeable appearance.

Hollow external walls are almost sure preventives against damp, and by their adoption in exposed localities the dwelling is not only rendered drier, but is made warmer in winter and cooler in summer. They consist

of two thicknesses of brickwork separated by an air space of 2 or 3 inches, with a carefully devised admission of outer air, which should circulate through the hollow spaces. The two thicknesses should be tied together by bonding ties of iron; bricks are not recommended for this purpose, for any existing outside moisture can be absorbed by the end of the brick, and through it conveyed inwards, thus neutralising the benefit that would otherwise be derived. A damp-proof course is needed at the top of exposed walls, such as parapets and chimneys; this is usually provided by finishing the top of the wall either with a stone or letting it project an inch or two over the side, or else having an impervious damp-course laid in the wall or chimney at its junction with the roof.

During the building of house walls, care should be taken that the chimney-flues are properly constructed. They should be made as straight as possible and separate one from another. The circular form is the best, as it is easy to clean, and the draught is more regular through it. They should contain no woodwork, and may with advantage be lined with a casing of sheet-iron, an arrangement which not only disconnects the flue from the house structure, but favours cleansing and the maintenance of an up-draught. All chimneys should be higher than surrounding buildings, so that they may be in no way sheltered when the wind is in a certain direction, nor a down-draught set up.

Defects in roofs of buildings are a frequent cause of dampness. The more common materials used in making roofs are slates and tiles, and less often, thatch, wood, zinc, and corrugated iron. Slates should be hard yet not brittle, free from streaks or flaws, and give a metallic ring when struck. They should not absorb more than 5 per cent. of water in twenty-four hours. If stood half their depth in water for several hours, the moisture should not rise to the top. They should be uniform in size, thickness, and colour, roughish and not greasy on the surface, free from white iron pyrites, and from large crystals of yellow pyrites; if of poor quality they are apt to scale and readily break away. Tiles, like bricks, are made of clay, but need more careful drying and burning. They should be hard and as little absorbent of water as possible. Thatch forms a warm and dry roof, but is very liable to be infested by birds and vermin; the danger from its liability to fire is great, and on this account it is seldom used. Wood is also used, but is open to the same objection. Zinc and corrugated iron are not suited for dwelling-houses; they are extremely hot in summer and cold in winter. In all buildings it is important to see that there is a framework sufficiently strong to bear the weight of the material, and in addition a certain amount of snow. In England this is not likely to accumulate to a greater depth than 6 inches, and may be taken at 5 lb. per superficial foot of horizontal surface.

The framework is usually made of wood. The angles of roofs for different coverings are as follows:—Zinc, 4°; large slates, 22°; ordinary slates, 26°·3; pantiles, 24°; thatch of straw, 45°; plain tiles, 45°. House roofs should always be covered with boarding laid at right angles to the rafters, and, if possible, some non-conducting material between this and the slates, such as "slag-felt," which not only makes the house cooler in summer, but warmer in winter. Laths are nearly always substituted for boards in roofs; this should not be, as they are much less satisfactory. When slates are used they should be fastened to the boards with zinc nails; composition nails are sometimes used, but the heads break off. If iron nails are used they should be galvanised, or boiled in linseed oil.

The part of each slate exposed to view is called the *gauge*. The *lap* is

the distance which the lower edge of any course overlaps the slates of the second course below, measuring from the nail-hole; it should not be less than 2 inches, but 3 inches is better. The flatter the pitch the greater the lap required. Tiles are often fastened with wooden pegs or hung on two special projections. Zinc and iron roofs are laid nearly flat in widths, with their edges overlapping to allow for expansion and contraction. The gutters round chimneys and party-walls where they join the roof are frequent places for leaks. They all should be made of lead, the edges of which should pass well into the brickwork; cement, if used for this purpose, is liable to crack. The eaves of roofs are finished in different ways. If eaves-boarding is used, they should come out some distance beyond the walls, and be provided with a gutter so as to throw off the rain well away from the house. These gutters should be made of cast-iron. For an ordinary roof they may be 5 inches deep with a slope of 1 in 10 inches; but they are usually fixed horizontally for appearance sake, and must then be larger than is necessary to carry off the water. The gutters should discharge into rain-pipes made also of cast-iron, 4 inches in internal diameter and placed at intervals of 50 feet. These rain-water pipes should discharge into properly ventilated rain-water tanks, or over a drain covered by a grating. They should never be directly connected with drains or sewers, neither should they be placed with their heads just below bedroom windows, more particularly when they empty into a tank.

For the inner walls of a house, the use of plaster of a coarse quality covered by a thin layer of a finer kind is almost universally adopted to cover the internal wall surfaces; this surface is generally papered. This practice has many disadvantages; the plaster, being porous, absorbs the moisture of the internal air, and with it any organic matters present in the air of inhabited rooms; while paper, unless varnished, cannot be washed, and much dirt sticks to it. The flock papers and their cheap imitations are particular offenders in these respects. Limewashing is preferable to unglazed and flock papers. In all cases where it is necessary to repeat lime-washing, the wall should be first scraped and the old coat thoroughly removed.

Floors are best made of impervious materials which can be washed. Wood, stone, or tile constitute the chief. Stones or tiles are suitable for sculleries and passages, but are cold for kitchens and living-rooms. Wood makes the best flooring, particularly if of hard wood, such as oak or teak, laid as parquet flooring. These, however, are very expensive. The ordinary wood floor is generally made of deal. If made of deal, a floor can be well laid down, provided that care be taken to tongue and groove the planks which constitute it. Cracks and crevices in floors should be avoided, as the enclosed space below, between them and the ceiling of the next room, is apt to become a huge receptacle for dirt of all kinds. In the commonest description of floors, the edges of the boards are merely placed true, and the boards are laid side by side as close as possible and then fixed by one or two nails driven into each joist. Their edges are then said to be *plain* or *butt-jointed*. This mode of laying boards is only tolerable in inferior buildings, as open joints invariably occur, owing to the unavoidable shrinkage of the boards. The *grooved* and *tongued* joint consists of forming a groove or channel along the edge of one board, and a projection or tongue which resembles a continuous tenon to fit it on the edge of the other board, each board having a groove on one edge and a tongue on the other. When face-nailed, each board should have two nails where it crosses the joist. Skirtings are employed to hide the joint between the walls and floor-boards. They should, where possible, be of tiles, iron, or cement, but if of wood, they

ought to be let into a groove in the floor, a device which will serve to prevent draughts coming through, and also the accumulation of dust in the holes and cracks which are invariably formed by the shrinking of the joints and skirtings.

When rooms in consecutive storeys are only separated by a single floor, measures must be taken to prevent the passage of sound and smell. "Slag-felt," a patent preparation of slag-wool, has remarkable properties of deadening sound; it further has the advantage of being fireproof, and does not harbour vermin. "Pugging," which generally consists of plasterers' rubbish, sawdust, tan, chopped straw, dried moss, &c., is objectionable, and should not be used for obvious reasons.

It remains now to consider a few of the chief points as to the design and arrangement of dwelling-houses. The chief object should be to make every use of the whole space in order to get as much accommodation and comfort as possible. If possible, rows of houses should run north and south, and all square buildings should have angles in these directions, so as to get

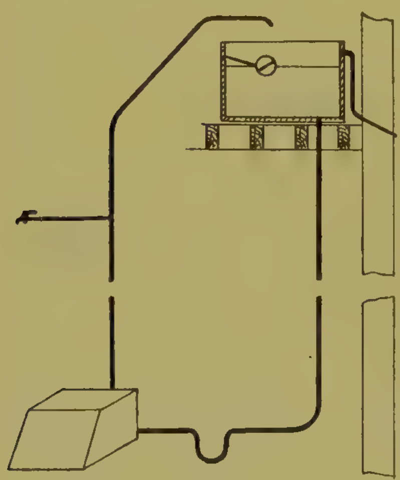


Fig. 54.
One-pipe Method of Domestic Hot-water Supply (after Bennett).

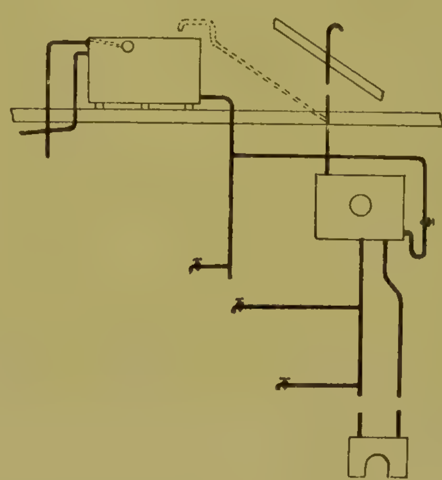


Fig. 55.
Tank System of Domestic Hot-water Supply (after Bennett).

some sunlight in every room. In many modern houses the most frequent error is, perhaps, the cramped space allowed for halls and staircases. Plenty of space should be given for them, as, with ventilating windows at the top, they constitute the central ventilation of the house. All the rooms should be so placed as to get light and air directly from the outside; and if there be any passages or lobbies they should be similarly lighted and aired. No room or closet which is not in direct communication with the outer air ought to be used as a sleeping-room.

The size of rooms will depend upon questions of cost, convenience, and the purpose for which they are intended. The height of rooms should not be less than 9 feet and rarely need exceed 12 feet. Every room should have at least one window in it which opens to the outer air direct; it should open half its size, extending nearly to the top of the room and equal in area to at least one-tenth of the floor space. In addition, every habitable room must have a fireplace, and ought also to have some ventilating aperture, the sectional area depending on the size of the room and the number of occupants.

In the construction of dwellings, one of the most important points is to select a proper position for water-closets. They should be placed in a

separate or outstanding part of the house; and where there are several water-closets, these ought to be built one over the other, and quite confined to one part of the building. The closets themselves should be of the best construction and efficiently disconnected from the drains.

Each closet ought to have at least one window of a minimum superficial area of 2 square feet opening direct into the outer air, and also have some means of special ventilation, so as to secure a circulation of air independently of that of the house. The floor and walls to a height of 5 or 6 feet should be of glazed tiles, and the remainder of the wall and ceiling ought to be varnished or painted.

The more detailed account of the ultimate disposal of the contents of water-closets, &c., as well as their form and construction, is given in chapter xii.

Hot-water Supplies.—The supply of hot water constitutes an important feature in every dwelling, and various systems have been suggested. The earliest form was the *one-pipe method* (Fig. 54), which consisted of a large riveted iron boiler fixed in an open fireplace and connected by a pipe to a cold-water cistern fixed above the highest fitting to be supplied with hot water. On the introduction of small boilers with closed ranges, together with circulating pipes and a hot-water reservoir of some kind for storing hot water, the one-pipe method gave way to the tank system. The *tank system* (Fig. 55) consists of a cold-water cistern and a hot-water tank fixed above the highest fittings that are required to be supplied with hot water, the boiler being placed usually behind the kitchen range. There are various modifications of this system. In most cases the flow-pipe is used also as the draw-off to the various fittings, but this presents the disadvantage that if the cold-water supply runs short the whole of the hot water in the cistern and pipes may be drawn off, unconsciously, and lead to serious results. To remedy this, another pipe taken from near the top of the hot-water tank should be introduced to supply the draw-offs to the various fittings.

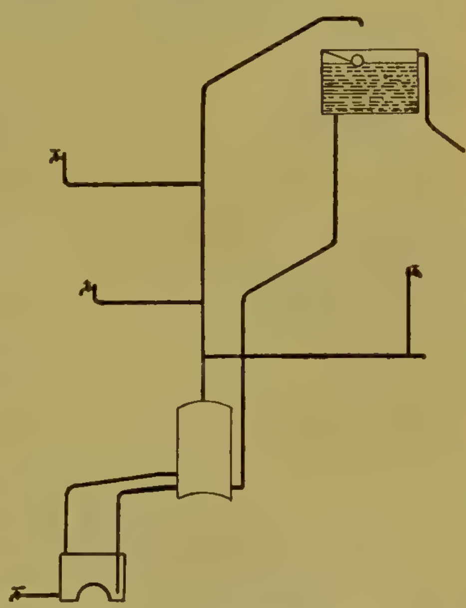


Fig. 56.—Cylinder System of Domestic Hot-water Supply (after Bennett).

The next development was the *cylinder system*. In this (Fig. 56) the hot-water reservoir is placed below or nearly on a level with the various fittings to be supplied with hot water, whereby, hot water being drawn from the top of the cylinder, it cannot be emptied and, should the cold-water supply to the cylinder fail, no hot water can be drawn from the taps. By this arrangement the boiler, circulating pipes, and cylinder must remain full of water. In the best types of this kind of hot-water installation, the cylinder is fixed as close as possible to, and one or two feet above, the boiler level. When fittings supplied with hot water are some distance from the cylinder, the hot water in long lengths of pipe, being stagnant, soon cools, and annoyance is caused by having to wait until the cold water in the pipes is run off before hot water can be obtained. To overcome this, a method known as the cylinder system, with secondary flow and return, is often adopted; it involves simply the supply-pipe being returned with a slight fall direct

to the cylinder again, and from this pipe a short branch taken to supply the various fittings with hot water. In all cylinder systems, a pipe, variously called the "expansion," "exhaust," or "rising main," is taken from the top of the cylinder vertically or obliquely, but never horizontally, and terminates either through the roof or, preferably, over the cold-water cistern. From this pipe all the hot-water taps are supplied.

As all the three foregoing arrangements present certain inconveniences, the combined or *cylinder tank system* has been introduced. This arrangement (Fig. 57) consists of a boiler, the cylinder, the hot-water tank, and the cold-water cistern. The cylinder is fixed as close to the boiler as convenient, and the hot-water tank above the highest fittings to be supplied. The cold-water cistern is placed above the hot-water tank. In the example drawn, the cold-water supply is taken direct from the cold-water cistern to the cylinder; the secondary flow and return pipes from the cylinder to the hot-water tank enter at the bottom of the hot-water tank, making this tank practically a circulating pipe of enlarged proportions. With pipes arranged in this manner, baths, lavatories, and sinks can be well supplied with hot water in all parts of a house.

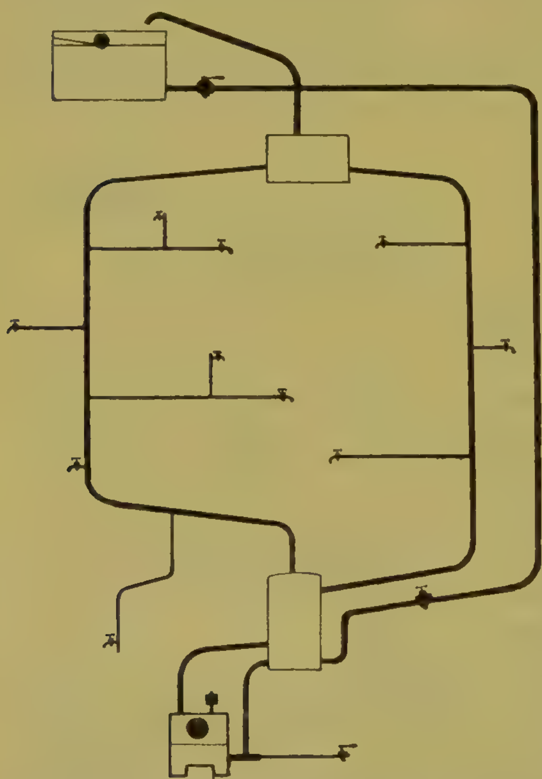


Fig. 57.—Cylinder Tank System of Domestic Hot-water Supply (after Bennett).

Although the cylinder tank system has the advantages of both the tank and cylinder systems, the whole of the installation may be spoiled if the two hot-water reservoirs are too large. It must be borne in mind, also, that the amount of hot water supplied depends not so much on the particular system adopted, but on the size and efficiency of the boiler; and it is much better to have a boiler large enough to do the work comfortably than to keep it and the fire at high pressure in order to be able to supply an average amount of hot water. Another point to be remembered is that, while domestic hot-water supply systems may under ordinary circumstances be considered safe, occasions are liable to occur which render them quite the reverse; the actual catastrophe being a kitchen boiler explosion. The cause of these boiler explosions may be brought about in three different ways :—(1) By the incrustation of lime or rust deposits in the boiler; (2) by the use of stop-valves on the circulating pipes; (3) by frost. As a rule, the first cause is rare, as the deposit grows slowly and in so doing closes up the bore of the pipe gradually; synchronous with this occlusion of the pipes there is a reduction of delivery of water, and the occurrence of alarming noises which suggest an examination of the apparatus before any actual harm is done. The use of stop-valves is a more serious matter. These valves are resorted to when two boilers are connected to one cylinder, or where the house is supplied with water of high temporary hardness, as conveniences to facilitate the periodic cleaning out of the boiler. If these

valves are meddled with by persons who do not understand their uses, or they are inadvertently left closed when they should be open, the possibilities of the boiler being exposed to a strain, from enclosed steam under a high pressure, which it cannot withstand, are readily imagined. Frost is undoubtedly the chief cause of domestic boiler explosions, and it is important that hot-water pipes should be protected from frost, or the whole of the apparatus may become a source of great danger. Should the expansion pipe become blocked with ice during a severe frost or, from similar cause, any part of the circulation be occluded, the only means of exit for the heated water and steam in the boiler is sealed up. Quite unconscious of danger, the firing of the boiler continues, with the result that the water has no room to expand, and continuing to receive heat from the fire, it stores up energy in proportion to the pressure on, and the quantity of the water contained in, the boiler and pipes. Now the ordinary type of kitchen boiler, not being constructed to withstand such an enormous strain, it follows that it bursts. The best means of obviating such a disaster is to fix a safety-valve either directly on the boiler or on a pipe carried a short distance from the boiler free from bends or angles. It must be fixed in an accessible position, and in such manner as to prevent the deposition of soot and dust on the safety-valve.

Another accident which may occur in these hot-water supply installations is the collapse of the cylinder. This is rare, but occurs usually as the result of frost causing an occlusion of the outlet of the expansion pipe and also of the supply pipe to the cylinder. As the fire cools down during the night, there is a corresponding cooling and contraction of the boiler and cylinder contents. If this continues, a partial vacuum forms in the cylinder, followed by its collapse from external atmospheric pressure. The only remedy is the placing of a valve on the cylinder to adjust automatically the inner and outer pressures.

Residential Flats.—Under modern conditions of life, especially in towns, the attainment of the desired essentials is becoming increasingly difficult, and a variety of new problems as to construction of dwellings have come to the front. Probably the most important of these is, how to obtain sufficiency of light and air. One practice in this country is to adjust the height of buildings to the width of streets, but a little consideration will show that the orientation of a street affects seriously the incidence of the sun's rays even in the same degree of latitude. Tables have been published showing the width in feet of streets in the latitude of London necessary to secure one to six hours of sunlight upon houses 40 feet high situated in streets orientated north and south and at angles with the meridian increasing by 5° until reaching 90° of orientation—that is, streets orientated east and west, at the winter solstice, the vernal and autumnal equinoxes, and the summer solstice.* The facts show that, in the latitude of London, at least, streets as wide as the houses are high will secure six hours' sunshine in streets at all angles to the meridian at the summer solstice, and four hours' sunshine in meridional streets at the equinoxes; if the width be increased to one and a half times the height of the houses, six hours' sunshine will be secured in all streets at the equinoxes and three hours in meridional streets at the winter solstice. If the width of the street be increased to two and two-third times the height of the houses, an extra hour of sunlight will be obtained in north and south streets at the winter solstice, but it will not be until the street is widened to three and three-quarter times the height of the houses that an hour's sunshine is obtained upon the lower

* Shirley Murphy: Annual Report to the London County Council, 1898.

parts of houses in east and west streets during mid-winter. If we limit the height of houses to the width of street, an angle of 45° is reached in London by the sun's rays in the first weeks of April and September, so that for five months the rays are above this angle, but during seven months of the year below it. The angle at the vernal and autumn equinoxes is 38½°. Trelat * has suggested an angle of 35° as necessary to secure sufficient penetration of the sun's rays into ground-floor rooms in towns. To secure this the streets must be, however, half as wide again as the houses are high. This would extend the sunshine period to nearly seven solar months (Fig. 58). A diagram is given by Stübben † showing the propor-

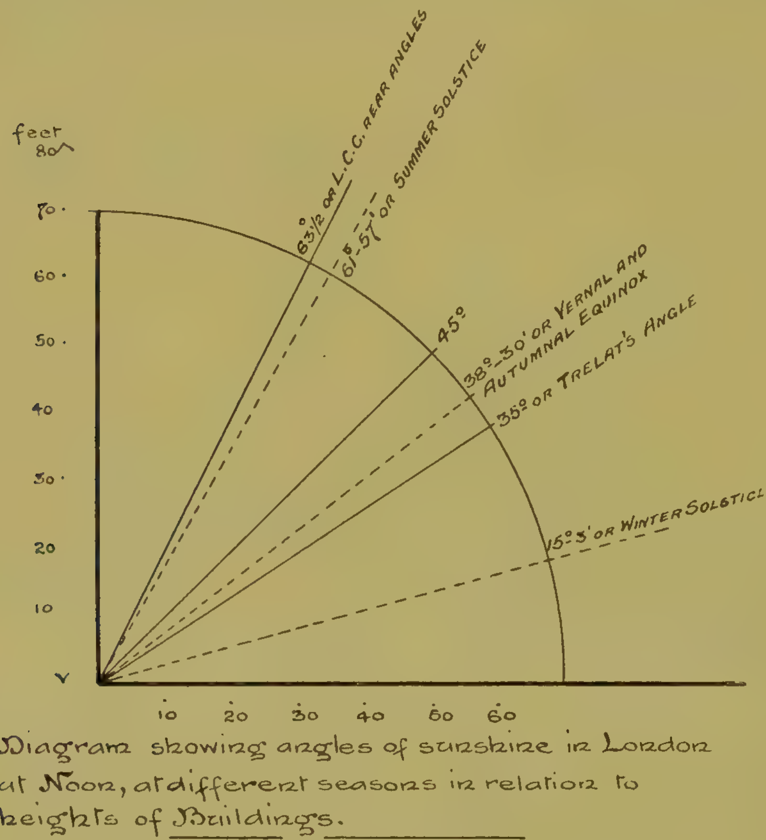


FIG. 58.—BUILDING ANGLES (AFTER SYKES).

tions between the width of streets and the height of buildings required in a number of continental cities, and it is curious to note that the angle 45° predominates. The London Building Act of 1894 prohibits the raising of buildings in streets laid out since 1862 higher than the width of the street; it also prohibits the raising of buildings in other streets higher than 80 feet without the consent of the London County Council; this is equal to an angle of 58°.

While the width and depth of streets regulate the frontage height of buildings bordering on them, it does not ensure adequacy of light and air in the rear. This is a serious factor in all towns. By the London Act of 1894, an angle of 63½° only was obtained, that is, a vertical height equal to one and a half the width of the horizontal space opposite. In the case of two houses whose rear boundaries back upon each other, the two angles of 63½°, when measured from the rear boundary of each premises, gives a

* Trelat: *Revue d'Hygiene*, July 1904.
† Stübben: *Weyl's Handbuch der Hygiene*, vol. iv., Berlin, 1901.

space between the rear faces of the two buildings equal to the height of the buildings, that is, a total angle of 45°; but the value of this is discounted by allowing the diagonal line to be drawn over the building from the rear boundary of the premises at a height of 16 feet above the level of the streets laid out before the Act of 1894. As Sykes has pointed out, this permits of the rear of the bulk of London houses to be built up solid to 16 feet from pavement level provided this interferes with no ancient lights.*

In large buildings, especially blocks of flats, open areas enclosed on all sides are a common feature. These need to be carefully watched. By section 45 of the London Building Act it is provided that, when the depth of the well or court from the top of the parapet to the ceiling of the ground storey exceeds the length or breadth of the court, provision for ventilation must be made by means of a communication between the lower end of the court and the outer air. It is desirable that this be safeguarded by some definition as to sectional area and the securing of continuous patency. As many of these courts have windows of habitable rooms opening into them, it is desirable that some minimum width of the court be laid down; we are disposed to place this at one-third the depth. In the ordinary type of domestic building, and having windows on at least two sides or fronts, on one of which the windows of a staircase also open, perflation of air can be obtained either horizontally on each floor through the rooms, or both vertically and horizontally by means of the stairway. In flats, the separate dwellings have no internal staircases, and are dependent entirely upon horizontal perflation from one front to the other of each of the separate dwellings. In these cases it is necessary to provide for the free horizontal perflation of all corridors and passages in flats, particularly when they are internal and have no vertical ventilation. Internal

FIG. 59.—PLAN OF FLAT (AFTER SYKES).

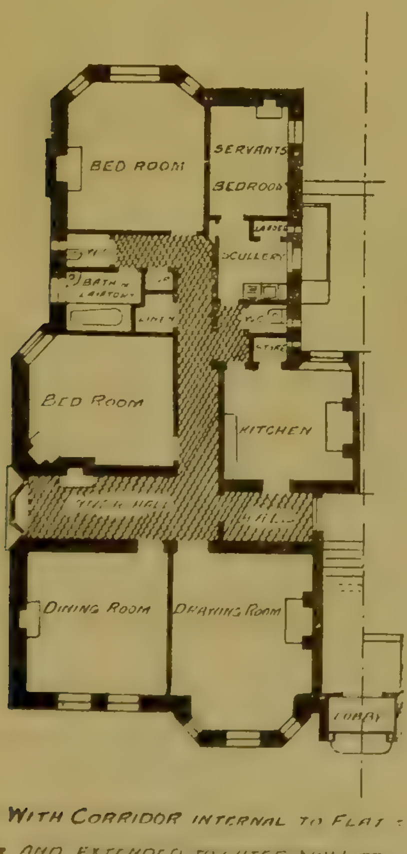
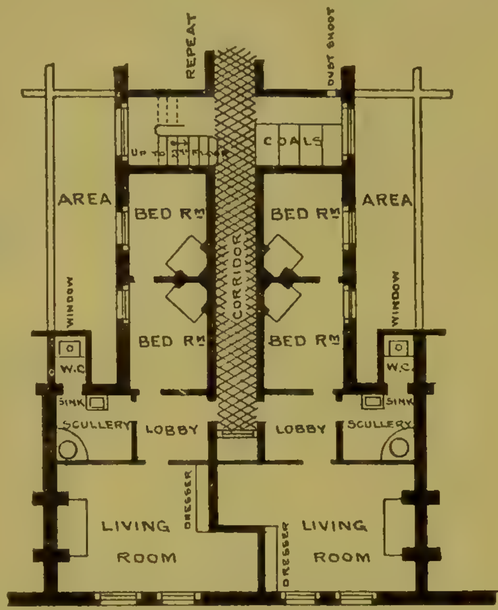


FIG. 60.—PLAN OF FLAT (AFTER SYKES).

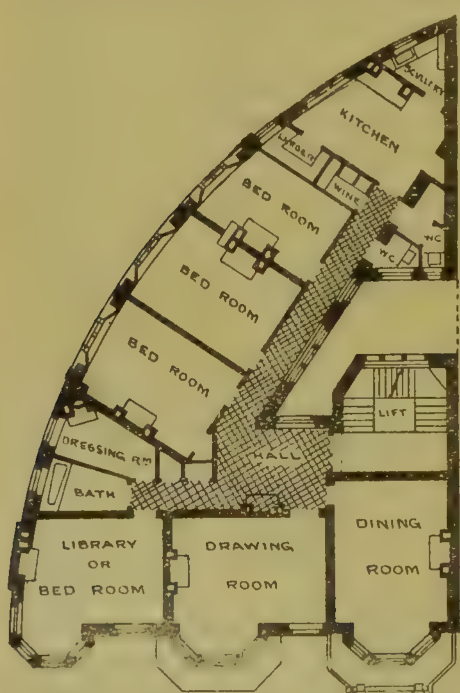
* Sykes: "Public Health and Architecture," *Public Health*, December 1904. This article enters fully into this question, and should be consulted.

corridors in flats without light and air constitute a serious danger to the health of those dwelling in the building. Figs. 59 and 60 illustrate some common types of flat. If the corridor is straight and terminates against an outer wall with a window, the conditions are such that both light and air are obtainable; if the corridor turns at right-angles to gain an outer wall and a window, air may be obtained, but light will be local and small. The most satisfactory condition is for a horizontal corridor to be so arranged as to be capable of through ventilation and suitable lighting. In some small flats the corridors are outside the flat; if so arranged as to be central and between the double row of rooms, they become dark *cul-de-sacs* and cut off some of the dwelling on one face of the building from access to the other face (Fig. 61). On the other hand, with a lateral corridor it is possible not only to light and open the corridor to the air, but also to provide windows in the back walls of the rooms, all of which may be on one face of the building (Fig. 62). This permits of direct access to the lighted and aired corridor, as well as through ventilation of the dwelling. Unless we are to revert to all the objectionable conditions of the old back-to-back houses, it is clear that the greatest supervision is needed to be made as to the planning of residential flats. Owing to the absence of an internal stairway in these dwellings, there is no reservoir of air, and no vertical but only horizontal perflation of air; it is therefore supremely important in them to obtain through ventilation. We must aim at making the dwelling, and not the building, the unit of sanitary administration, therefore the minimum requirements to be demanded in the case of all flats should be:—(1) that the building be in conformity with Acts and bye-laws as to damp courses, dry areas, and concrete basements; (2) that the water-supply and drainage be in accordance with the bye-laws and regulations; (3) that the common staircase be permanently ventilated at each floor level or by through ventilation, so as



WITH CENTRAL CORRIDOR EXTERNAL TO FLATS

FIG. 61.—PLAN OF FLAT (AFTER SYKES).



WITH LATERAL CORRIDOR EXTERNAL TO FLAT

FIG. 62.—PLAN OF FLAT (AFTER SYKES).

to break the common air connection; (4) that each flat or dwelling be so arranged as to be ventilated through from one front to another; (5) that each habitable room be at least 8½ feet in height and 96 square feet in area, and have a fireplace with chimney-flue; (6) that on each floor there be at least one draw-tap and sink with a constant supply of water thereto, for every ten occupants or less; (7) that there be on each floor one water-closet properly and efficiently supplied with water for each ten occupants or less, the closet being disconnected aerially from any dwelling in the interior of the building; (8) that a proper place for the storage of food, ventilated into the open air and protected from flies, be provided for each floor; (9) that on each floor a sufficient space or open lobby be provided for each family to deposit refuse; (10) that all corridors within the building, whether external or internal to the dwellings, be sufficiently lighted and ventilated.

Artisans' Dwellings.—In selecting a site, it is of great importance to secure sufficient area, a well-drained subsoil, and a suitable aspect. The buildings should occupy about one-third of the entire site, leaving two-thirds for air, light, approaches, &c. The height of the buildings should not exceed five storeys above the ground, on account of fatigue in ascent and obstruction of light and air. The yards are best spread with a 9-inch layer of cement concrete laid to falls for drainage; it may be finished with a coating of tar-paving.

Staircases in blocks of artisans' dwellings should be built against an outside wall, so that windows may light them; the staircase should be made of stone or concrete, so as to resist the action of fire. The minimum width should be 6 feet 9 inches.

Internal corridors are specially to be avoided, as they are difficult to light and consequently are usually dirty.

The internal arrangement of a tenement should, as far as possible, assimilate to that of a well-planned country cottage, the size and number of the rooms depending upon local circumstances. A convenient size for the living-room or kitchen is 11 feet wide by 13 feet from front to back, the fire-place being so placed as to afford ample room in case of emergency for a bedstead. The windows should not be less than 3 feet 6 inches in width, and should extend to within 6 inches of the ceiling, in order to obtain the utmost light and ventilation. The room should be fitted with a cooking-range 3 feet in width and provided with an oven. A food store, ventilated from the external air, should also be available. In the Peabody Buildings the sinks as well as the water-closets are on the staircase landings, and used jointly by the occupants of two or more tenements; they should be open to the constant inspection of the superintendents.

The bedrooms vary in size; usually they are about 13 feet by 9 feet. Fanlights over the doors are useful as ventilators. Every bedroom should have a fireplace which will act as a ventilator.

The Model Bye-laws of the Local Government Board suggest 300 cubic feet of air space for each adult and 150 for each child as a minimum in a sleeping-room; it is necessary, therefore, to provide floor space equivalent to at least 6 feet 6 inches by 5 feet for each adult, and 5 feet by 5 feet 3 inches for each child.

In the country more space is available, and a labourer's cottage comprises generally a living-room with a small scullery attached, and sufficient bedroom accommodation. The most economical arrangement is found in a two-storeyed building, the height of the lower storey of which should be 9 feet, and that of the upper not less than 8 feet. The living-room should have a minimum floor area of 150 square feet and be fitted with a cupboard

for storing food, also lighted and ventilated by a separate window. The scullery adjoining the living-room should be 10 feet by 7½ feet; and there should be, if possible, a well-lighted, cool and dry pantry with an entrance from the scullery. The bedrooms for adults should have at least 80 feet of floor area, and those for children 50 feet. All the rooms should have fireplaces. The privy accommodation and places for deposit of refuse are in these houses best placed out of doors. They should be conveniently placed and afford as much privacy as is possible.

SCHOOLS.

The dominant idea in all modern school construction is to have a large central assembly hall in which all the pupils can meet, and from this hall the class-rooms are made to open. Where the site is limited and a central hall is desired, this hall should be separated entirely from the class-rooms by naturally aerated corridors, so that the air of the large hall, vitiated by the emanations of a large number of children, shall not, as it otherwise does, pass directly into the side rooms. In cases where the site is adequate, it is better to isolate the assembly hall, placing then the class-rooms in another building or buildings, and on one side only of a corridor, which itself should have ample windows. For small schools, a school-room with one or more class-rooms will be sufficient, but there should be always at least one class-room, except in special cases. Where the site is sufficiently large and level, the most economical plan is that in which all the rooms are on the ground floor, but circumstances may compel the building to have three floors, but it is desirable that a public elementary school should be on not more than two floors. According to the policy of the Board of Education, where there is a central hall it should have a floor space of not more than 4 square feet for each scholar, and be fully lighted, warmed, and ventilated. Large schools not built with a central hall must be provided with a wide corridor from 8 to 12 feet wide, giving access to the rooms. The site area may be taken to average a quarter of an acre for every 250 children.

Where a school-room is the principal room in a school which has neither central hall nor corridor, it should never be designed for more than 100 children. No school-room is desirable which is lighted from one side only. When a school consists of a single room, that room should not contain more than 600 square feet of floor space. The class-rooms should not be passage-ways from one part of the building to another, nor from the school-room to the play-yard. As a rule, class-rooms should not be planned to accommodate more than sixty nor less than twenty-four children. In the absence of supplementary light, the measurement of the window wall in a room 14 feet high should not exceed 24 feet 8 inches. When a building is for the use of older scholars, the school-room and class-rooms must show an average of not less than 10 square feet of floor space for each place proposed to be provided; in infant schools, an average of not less than 9 square feet for each place may be accepted. In the higher elementary schools a minimum of 12 square feet per scholar is requisite. In no case should a central hall or corridor be included as counting towards the accommodation available. The wall of every room used for teaching must be at least 12 feet high from the floor to the ceiling; if the room area exceed 360 square feet, the height should be 13 feet; and if it exceed 600 square feet, then the height of the walls must be 14 feet. Roofs open to the apex are un-

desirable in schools. Structurally all school buildings should conform to the requirements laid down for ordinary dwellings.

The seats and desks provided in schools should be graduated according to the ages of the scholars, fitted with backs and placed at right angles to the window wall. An allowance of 18 inches per scholar at each desk and seat will suffice, except in the case of the dual desk; and the length of each group should be, therefore, some multiple of 18 inches, with gangways of 18 inches between the groups and walls. In the case of the dual desk, the usual length is 40 inches and the gangways 16 inches. In an ordinary class-room five rows of long desks or six rows of dual desks are best, but in rooms providing for more than sixty children there should not be more than four rows of long desks or five rows of dual desks. Each desk should be inclined at an angle of 15°, and its edge, when used for writing, should be vertically over the edge of the seat.

The lighting of school- and class-rooms is of vital importance. When left light is impossible, right light is next best; windows full in the eyes of scholars are objectionable. The sills of the main lighting windows should be placed not more than 4 feet above the floor; the windows should reach nearly to the ceiling, and the upper portion be made to swing inwards. Skylights are very objectionable. The ventilation and warming of rooms used for teaching are of paramount importance. There must be ample provision for the continuous inflow of fresh air and for the outflow of foul air. The best way of providing the latter is to build to each room a separate air-chimney, carried up in the same stack with the smoke-flues. An outlet should be alongside a warm flue, otherwise it will act often as a cold inlet. Inlets are best placed in corners of rooms farthest from doors and fireplaces, and should be arranged to discharge upwards into the room. Gratings in floors should never be provided. The ideal temperature for a school- or class-room is from 56° to 60° F. Where possible, this warming should be secured either by means of open fireplaces or by hot-water pipes. Common closed stoves are most undesirable, and should be permitted only when provided with proper chimneys, of such a pattern that they cannot become red-hot, are supplied with fresh air, direct from the outside, by a flue of not less than 72 inches superficial, and of such a size or shape as not to interfere with the floor space necessary for teaching purposes. All fireplaces and stoves need to be protected by guards.

As regards school dormitories, the usual width of the room in the Poor Law schools is 18 feet, each bed having a minimum of 3 feet 9 inches of wall space, 36 feet of floor area, and 360 cubic feet of space. If the room is only 15 feet wide, the wall space is increased to 4 feet. There is reason to believe that very few private schools, even those of the better class, afford more than 300 cubic feet of space per head in their dormitories, an allowance which is quite inadequate. Dukes advocates for this climate 800 cubic feet of space with some 70 square feet of floor area for each child in all school dormitories, and certainly the amount of ventilation necessary to keep a smaller space wholesome would be found almost intolerable in cold weather.

The system of closed cubicles adopted in some of the large public schools is to be condemned on sanitary grounds; neither should dormitories be used as places to study in during the day. The ventilation of dormitories should be carefully seen to. Where gas is used for lighting, means should be adopted to carry off the products of combustion, so as not to deteriorate the air; on no account should it be used for heating purposes.

In school lavatories, supervision needs to be exercised to see that all

children wash daily, and that no two of them use the same water. Each child should have a separate towel, and the use of roller towels forbidden. The regulations of the Local Government Board lay down that bathing arrangements in the Poor Law schools must admit of every child being bathed at least once a week in winter and twice a week in summer, and certainly in other schools the bathing facilities ought not to be less.

The amount of closet accommodation for schools is of importance; it should be at least 15 per cent. for girls, and 10 per cent. for boys with, in addition, 5 per cent. of urinals. The closets should be placed out of doors at a convenient distance and well lighted. The kind best adapted for schools is the trough or flush closet. Several schools have tried the dry-earth system, but with only partial success; for obvious reasons it is a most unsuitable type of closet for girls.

In all schools a proper cloak-room should be provided. The result of heaping together a mass of foul garments may be easily imagined; zymotic disease or vermin may be disseminated, and clothes acquire a disagreeable odour.

Influence of School Attendance on the Spread of Disease.—This question has received much attention from time to time, and resolves itself broadly into the influence of (*a*) residential schools, and (*b*) ordinary day schools. In the former class of school the influence of the establishment upon the health of the children is, of course, likely to be much more pronounced than in the case of the latter. The ill-effects associated with life in residential schools have been noticeable chiefly in connection with the working of two kinds of schools, namely, the Poor Law schools and those of the Industrial and Reformatory system, in both of which repeated outbreaks of ringworm and ophthalmia drew attention to this matter. In 1875, Nettleship made a Report on Ophthalmia in the Metropolitan Pauper Schools; in 1896 a Departmental Committee of the Home Office reported on the Reformatory schools; and soon after a Departmental Committee of the Local Government Board reported on the Poor-Law schools. All these Reports laid emphasis on the evils of overcrowding upon the health, and mental and moral development of the children. Given suitable sanitary conditions in the day-rooms, dormitories, dining-halls, and school-rooms, the occurrence and spread of ophthalmia, ringworm, and skin complaints generally should be reduced to a minimum. Probably the most powerful factors for improvement have been the abolition of common lavatory basins, the introduction of the spray system of washing, and the setting apart for the use of each individual a separate brush, towel, &c. The tendency of late years has been to regard the aggregation of children in barrack schools as a mistake, and there can be no doubt that the more these children are subdivided into small or independent houses the better will be their health, assuming, of course, that past errors as to a rigid adherence to ill-regulated and insufficiently varied diet scales be avoided.

When we analyse the influence of ordinary day schools upon the spread of disease, we find that it is mainly operative in spreading direct infection of such diseases as diphtheria, scarlet fever, measles, whooping-cough, and small-pox. This matter was discussed exhaustively in a Memorandum issued by the Local Government Board in 1884, and re-issued in 1890; in a revised form it exists in Article 88 of the Day School Code of 1900. This prescribes, as one of the general conditions required to be fulfilled by a public elementary school in order to obtain an annual Parliamentary grant, that

the managers must at once comply with any notice of the Sanitary Authority of the district in which the school is situated, requiring them for a specified time, with a view to preventing the spread of disease, either to close the school or to exclude any scholars from attendance, but after complying they may appeal to the Department, if they consider the notice to be unreasonable.

The diseases for the prevention of which school closure, or the exclusion of particular children, will be required, are principally those which spread by infection directly from person to person, such as scarlet fever, measles, diphtheria, whooping-cough, small-pox, and rötheln, the order in which the several diseases are here given being about that of the relative frequency with which their occurrence gives rise to these questions at schools. More rarely, the same questions arise in connection with enteric fever and diarrhœal diseases, which spread not so much by direct infection from person to person as indirectly through the agency of local conditions, such as infected school privies.

It will be seen that Article 88, quoted above, confers upon Sanitary Authorities an alternative power with respect to public elementary schools, (*a*) to cause particular scholars to be for a specified time excluded from attendance, or (*b*) to require the school to be closed for a specified time.

First, as to exclusion from school of particular scholars, it may be laid down as a principle that all children suffering from any dangerous infectious disorder should be excluded from school until there is reason to believe that they have ceased to be in an infectious condition.

Secondly, as to the closing of schools, this, by more seriously interfering with the educational work of a district, is a much more grave step for a Sanitary Authority to take than to direct the exclusion of particular scholars. It is a measure that seldom ought to be enforced, except in presence of an actual epidemic, nor even then as a matter of routine, nor unless there is a clear prospect of preventing the propagation of disease, such as could not be looked for from less comprehensive action.

The Medical Officer of Health, on becoming aware of the presence of dangerous infectious disease in his district, should . . . send immediate notice to the teacher of the school or schools which the children of infected households may be attending, requesting that such children may be excluded from school for such time as he (the Medical Officer of Health) may specify as being necessary. Ready compliance with such request may often render formal action under Article 88 of the Education Code unnecessary.

The attention of school attendance officers and of schoolmasters should also be drawn to the following considerations. Frequently they themselves will obtain the earliest information of the occurrence of infectious disease among scholars, and it is most desirable that such officer or master should, without delay, communicate the facts to the Medical Officer of Health.

As regards duration of exclusion from school of particular children, the time to be specified will vary in different diseases and different cases, and in this matter the Sanitary Authority will doubtless be guided by the advice of their Medical Officer, who may properly be entrusted with some general duty of acting for the Authority in this subject-matter.

In deciding whether an outbreak of infectious disease among children of school age may be best combated by closing a school, or whether it will suffice to exclude the children of infected households, the two most important points to be considered are :—

The completeness and promptness of the information received by the officers of the Sanitary Authority respecting the occurrence of infectious cases.

The opportunities which exist for intercourse between the children of different households elsewhere than at school.

In places where there are several public elementary schools, if an outbreak of infectious disease be confined to the scholars of one particular school, it may be sufficient to close that school only. But where different schools have all appeared to aid in the spread of disease (though perhaps to an unequal extent) the Sanitary Authority may consider it advisable that all should be closed lest children in an infectious state who previously attended the schools that are closed should be sent to others that might remain open.

It must be remembered that Sanitary Authorities have no power in respect of Sunday schools or other private schools ; except in so far as these may contravene section 91 (5), section 126, or other provision of the Public Health Act, 1875 ; but it will often be expedient to invite the co-operation of managers of such schools in efforts for securing the public health. Experience shows that they are usually ready to defer to the representations of the authority responsible for the public health of the district.

Reports to Sanitary Authorities, advising the closure of a school or schools in any district are to be treated as "special" reports within the meaning of the General Order of the Local Government Board of March 1880, and copies of them should accordingly be sent to the Board. These reports should state the grounds upon which the Medical Officer of Health advocates the closure of the school or schools in preference to the exclusion of particular scholars.

All notices of the Sanitary Authority for the closing of public elementary schools should be addressed in writing to the managers, and should state the grounds on which the closing is deemed necessary.

All such notices should specify a definite time during which the school is to remain closed ; this should be as short a period as can be regarded as sufficing on sanitary grounds ; a second

notice may be given before the expiration of the first, if it should be found necessary to postpone the re-opening of a school. The managers of schools, after complying with the requirements of the Sanitary Authority, have the right of appeal to the Education Department, if they consider any notice to be unreasonable.

The London County Council have adopted the following rules with reference to the exclusion from school of children suffering from infectious diseases :—

(1) Children suffering from the following diseases must be excluded from school for the following periods :—mumps for one month ; chicken-pox at least two weeks, and until every scab has fallen off ; whooping-cough for as long as the cough continues, and not less than five weeks from the commencement of the whooping.

(2) Children coming from houses in which either mumps, chicken-pox, or whooping cough exist must be dealt with as follows :—(*a*) Children in schools other than infant schools who have not had the disease and all children in infant schools must be excluded ; (*b*) children in schools, other than infant schools, who have had one of the diseases need not be excluded.

(3) Children in infected houses and excluded from school under clause 2 (*a*) and (*b*), must absent themselves for the following periods :—when there is no medical attendant, three weeks ; when there is one, when he deems fit ; chicken-pox for two weeks ; whooping cough for two weeks.

Section (*b*) of clause 2, with regard to children other than infants, will be rendered useless, probably, by the requirements of the child's mother. If the mother wants to keep the child at home, it will not have had the disease ; if the mother wants to send the child, it will have had the disease. It seems to us that this manipulation of the child can only be prevented by the adoption of some such system as that employed in some German towns, in which a history or schedule accompanies the child throughout its school career, and on which is noted, amongst other things, the infectious diseases it has had. This document would be the equivalent of the ordinary medical history sheet as used in the army for recording the diseases of the soldier.

An exhaustive inquiry into the influence of school life on the spread of scarlet fever was made by Sir Shirley Murphy in his Report to the London County Council in 1894, and has recently been supplemented by a similar inquiry by Goldsmith * in respect of some 20,000 cases of the disease in Manchester. A review of these statistical inquiries shows that schools do assist in the spread of scarlet fever, but warrants the belief that the influence exerted is not so great as many believe. Both reports indicate that in schools there is a notable decrease in the number of scarlet fever cases during the holidays, amounting in infants to 8·4 per cent. and in children to 17·5 per cent. Again, in the period of the re-opening of the schools, while there is an increase among infants there is a much greater increase in the proportion of school children affected, such increase amounting to over 25 per cent.

It is, of course, essential that the work of educating the children of the nation should continue, but it is no less essential that they should be protected as far as possible. This would appear to lie in the direction of a furthering of the present policy of educating the school teachers to recognise the early symptoms and signs of the principal infectious and contagious diseases, and in the establishment of a thorough and systematic medical inspection of all school children. Apart from being a reliable line of defence in controlling the spread of infectious disease, there can be little doubt that such a medical inspector in schools would do much to advance the physical nurture and mental culture of the young by eliminating the unfit and otherwise safeguarding their welfare. There is every indication that medical inspection of all school children and schools will soon receive legislative sanction.

* Goldsmith: "The Influence of School Life on the Spread of Scarlet Fever," *Lancet*, 1907, vol. i. p. 1765.

HOSPITALS.

The term "hospital" includes a great variety of institutions having for their object the treatment and care of the sick. These institutions may be divided into two main sections :—(1) general hospitals, and (2) special hospitals.

General hospitals will include all the hospitals which receive all kinds of medical and surgical diseases except infectious fevers and chronic incurable and mental diseases. They include county infirmaries and the large and increasing class of buildings called cottage hospitals and the infirmaries built and administered under the Poor Law system.

Special hospitals include fever and small-pox, lying-in, consumption, children, incurable and chronic, convalescent, sea-bathing, eye, ear, throat, skin and cancer hospitals. This group of hospitals can be further and conveniently divided into (*a*) those not for infectious diseases, and (*b*) those for infectious diseases.

All that has been said in respect of site, surroundings, and construction of houses and schools applies with still greater force to hospitals. As charitable institutions, existing for the purpose of affording medical and surgical aid to the sick poor, hospitals, on economical grounds, have largely to be so constructed that the patients may be grouped together in general wards. It is this aggregation of large numbers of sick or diseased persons under one building that constitutes the most important factor in hospital hygiene. It has long been known that overcrowding in the wards of hospitals is productive of the worst results, particularly in surgical wards, where the neglect of proper sanitary measures produces the class of diseases known as "septic," of which well-known forms are erysipelas and blood-poisoning. Bearing this fact in mind, we are able to understand that the chief conditions to be avoided in all hospitals are :—(1) insufficiency of cubic space ; (2) inefficient ventilation ; (3) improper arrangements for the removal of excreta, refuse, soiled linen, dressings, poultices, &c. ; (4) faulty arrangements of the buildings.

General Hospitals should always be placed within a reasonable distance of the population whose needs they serve. This essential feature naturally raises a difficulty as to site, especially in the large towns.

In every hospital of whatever size there must always be :—(*a*) Administration offices ; (*b*) wards and their offices ; (*c*) operation-room, with subsidiary rooms ; (*d*) out-patient department ; (*e*) mortuary and *post-mortem* room ; to these will be added in the case of very large hospitals, (*f*) laundry ; (*g*) nurses' home ; (*h*) medical school.

The precise disposition of these several parts of the hospital, in relation to each other, of necessity greatly depends on the size of the hospital, and on the shape and area of the site. In Heidelberg, Berne, Baltimore, and several other continental hospitals, each of these departments has been placed in an absolutely separate building, and in some cases (Baltimore) unconnected by even covered ways. The drawbacks to this mode of arrangement are :—(1) the great extent of land necessarily occupied ; (2) the greater proportional cost of both land and buildings as well as of administration. The value of a sufficiency of open space about a hospital is undoubtedly very great, but in cases where the cost of land is so great as it is in London and some provincial towns the absolute necessity for so large an area of site per bed may reasonably be questioned. The chief defect usually met with in the older and in some of the newer hospitals is the absence of effective

separation of the wards from the other parts, with due regard to economy of construction. Consequently, it may be stated that the really essential principles which should guide us in constructing a hospital are, briefly:—(1) an avoidance of all intimate connection between the wards and the administration buildings; (2) separation of medical from surgical wards; (3) complete atmospheric disconnection between the wards on the one hand, and the mortuary, laundry, and out-patient department on the other.

To secure these results, the most common plan now is to build hospitals upon what is called the pavilion system. This system is merely the arranging on a plot of ground, of a series of one, two, or more storey buildings, called pavilions, and connecting them together by corridors or covered ways. The individual pavilions or blocks of buildings may be of any shape or size; the main essential is that care be taken to see that the various buildings are not so close to each other as to seriously interfere with the free circulation of air, or shut out light. A good rule to adopt is, if of two buildings one is higher than the other, the distance between them must be equal to

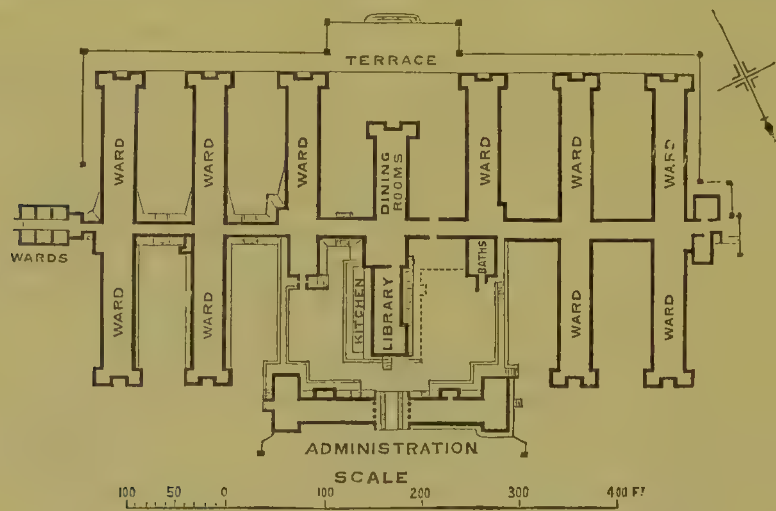


FIG. 63.—BLOCK PLAN OF THE ROYAL HERBERT HOSPITAL.

the height of the higher; if two buildings are of the same height, then the distance must be one and a half times their height.

While no particular hospital can be quoted as an ideal or perfect type of what a hospital should be both in planning and construction, still, as illustrating how the essential principles of the separation of parts can be complied with upon a comparatively small area of site per patient, few existing hospitals afford this object-lesson so well as the Royal Herbert Hospital at Woolwich (Fig. 63). The general arrangement of the *administration block* will necessarily vary with the size of the hospital. For a large building the offices will be numerous and the residential part extensive; but the modern custom of housing the nursing staff in a separate building very much reduces the amount of accommodation to be provided in the main administration block. In some modern hospitals, the kitchen offices, with the dormitories for servants, are placed in a separate block, thus still further reducing the main block. Practically, the administration block of most hospitals comprises the secretary's office, board-room, residences for medical staff, matron and secretary, steward's office, store-rooms, kitchen offices, and servants' dormitories. To these may be added a consultation-room for the professional staff and an office for the matron. The kitchen offices may be advantageously placed on the top floor, and the stores in the

basement, with communication between the two by means of a lift and speaking-tube. Separate dining-rooms should be provided for male and female servants.

Wards.—The ward of a hospital may be regarded as the central unit of hospital construction. The buildings in which they are placed should be detached, on the pavilion system, and so disposed as to obtain the greatest amount of air and light. With detached buildings the size of a hospital is dependent merely on the facility of administration.

There can be no doubt that the necessity for an unlimited supply of air is the cardinal consideration in the erection of hospitals, and, in fact, must govern the construction of the buildings. For many diseases, especially the acute, the merest hovels with plenty of air are better than the most costly hospitals without it. It is ill-judged humanity to overcrowd febrile patients into a building, merely because it is called a hospital, when the very fact of the overcrowding lessens or even destroys its usefulness.

In order to keep the air in a hospital pure, it is necessary to fix some standard for the minimum cubic space required by each sick person, and to provide for a change of atmosphere sufficient to maintain health, but not so frequent as to cause draughts. It may be laid down as a good rule that the number of patients under one roof or in any one pavilion should not exceed 100 to 120; for surgical cases, 80 to 100 would be better.

As a general rule, it may be said that large wards are more readily ventilated, warmed, and managed than small ones. The most general form of hospital wards is rectangular; but in a few hospitals they are circular; and in the Johns Hopkins Hospital, Baltimore, there are octagonal wards. The dimensions of wards are dependent upon the number of patients to be accommodated and the amount of cubic space to be allotted to each. Rectangular wards vary from 24 to 30 feet in width, 13 to 14 feet in height, and from 30 to over 100 feet in length. Each patient should have from 100 to 120 square feet of floor area, and from 1500 to 2000 cubic feet of air space. For fever, severe surgical or lying-in cases, the requirements are greater, being about 3000 cubic feet of air space and 140 square feet of floor area. Experience shows that nursing is best carried out when the number of beds in a ward do not exceed thirty or thirty-two. These beds are best arranged with their heads to the wall and facing into the ward. Each bed should be placed between two windows, or, at most, two beds in between two windows.

Where possible, the ventilation should be natural, *i.e.*, dependent on the movement of the outer air, and on inequalities of weight of the external and internal air. The reason of this is, that a much more efficient ventilation can be obtained at a cheaper cost than by any artificial means. Also, by means of open doors and windows, we can obtain at any moment a sufficiency of ventilation in a special ward, whereas local alterations of this kind are not possible in any artificial system. The amount of air, also, which any artificial system can give cheaply is comparatively limited. The amount of air should be restricted only by the necessity of not allowing its movement to be too perceptible.

Ventilation by windows and fireplaces, assisted by additional inlets and outlets, is the usual system employed in this country. Inlets are made independent of the windows; usually a Sherringham valve is placed near the ceiling, or a Tobin's tube with openings at about 6 feet from the floor level. If the incoming air is too cold, this may be warmed by passing it over a steam coil or hot-water pipes. It may further be filtered and

washed by passing it through moist canvas screens, as carried out at the New General Hospital in Birmingham.

Windows are best placed opposite one another, and should extend from 3 feet above the floor to within 6 inches of the ceiling; the upper part may be so made as to fall inwards and form a hopper ventilator. They should all be capable of being opened at their upper parts. One square foot of window area may be provided for every 80 cubic feet of space in the ward.

With an open fireplace in a ward, the chimney acts as an extracting shaft if a fire is kept burning, and for this reason it should be placed in the centre of a ward; it also distributes thence its heat more equably. As additional outlets, vertical shafts should be carried from the room to above the roof; these are best made of galvanised iron, and may be fitted at the top with a Boyle's ventilating cowl or some similar contrivance; they should be perfectly straight and vertical, any bends only cause friction. They should be of such a size as will ensure a moderate current of air through them. The movement of air in the shaft will depend on the movement of the external air, but will rarely be less than 3 or 4 feet per second. These shafts should never exceed 144 square inches in area. With proper inlets for air, these shafts will afford continuous and adequate ventilation, and may be supplemented as occasion requires by opening the windows. With a proper system of ventilation in which large masses of cold air are continually replacing a large volume of heated air, a proper system of warming the wards is essential. The open fire is not sufficient for this purpose, and this has to be supplemented by some other method. High-pressure hot-water pipes or low-pressure steam pipes carried round the outer walls of the ward is the most convenient arrangement. Sometimes pipes of different dimensions are used, so that each pipe may be turned on separately, or used in combination with another. This plan allows of the temperature of the wards being regulated to any degree of heat; it may be so arranged that the incoming air may be warmed by passing over some branch of these steam pipes, and this would prevent the feeling of draught from the cold air entering through the open inlets.

In some hospitals, as the Eppendorf Hospital at Hamburg, steam pipes are placed beneath the floor; in such an arrangement, which is generally applied to a building of one storey, the floor is laid with "terazzo" (pieces of marble laid in cement). This plan is inadmissible with wooden floors; under the flooring are a series of channels 2 feet 6 inches wide, in each of which runs a steam pipe, supported on iron rails. The steam is supplied by a boiler, each pavilion being provided with its own boiler. In addition, in each ward are two steam radiators, which are connected by tubes with the outer air.

This system of heating the floors of wards is now generally adopted on the Continent. It is claimed that it has the following advantages:—(1) It renders possible the use of an impervious material for floor surfaces; (2) that the greatest warmth is at the part needed, that is, nearest the feet; and (3) the air being constantly circulating, the system materially assists ventilation. In one-storey buildings, in place of outlet shafts as described above, ridge ventilation is usually resorted to; the best form is a "roof lantern" running about two-thirds the length of the ward.

The position of water-closets and sinks is a matter for careful consideration. The most complete severance of all atmospheric connection between the ward and the closets should be aimed at, and this is best attained when the closets are entered from an intervening lobby or from the open air. In some of the most recently built hospitals the form of the intervening lobby

is a sort of covered bridge, the object being to give as free play as possible to the air, so as to prevent stagnation in the vicinity of the ward. The removal of excreta must be by water, except in the tropics, where this plan is not always available. In hospitals, nothing else can be depended upon as regards certainty and rapidity. The best arrangement for closets is not the handle and plug, which very feeble patients will not lift; but a bell-pull wire or chain connected with a water-waste preventer that has a siphon action; a very short pull of the chain is sufficient to set the siphon acting and ensure proper flushing by the most careless persons. This plan is better than the self-acting spring seat, which is not always easily depressed by a thin patient. The number of water-closets required may usually be reckoned as one for every twelve beds. In close proximity to the closets should be a separate space, enclosed for a slop sink, and also for keeping bed-pans, &c. It should be provided with water for washing these vessels. The place should have ample light and preferably be provided with a glass panel in the door so as always to be under inspection. It should be ventilated direct into the outer air.

The floors of hospital wards should, if possible, be fireproof. Such a floor may be constructed of iron beams embedded in cement, on which is laid a solid and impervious floor surface. Solid oak or teak parquet laid on the surface of the cement is the best arrangement, but is expensive. Tongued floors of the same wood, with the intervening spaces filled in with white lead or marine glue, forms an excellent floor and is cheaper. Such floors, if properly laid and of well-seasoned wood, when paraffined, form a practically impervious solid surface. The paraffin treatment of floor surfaces is as follows:—The paraffin is melted and then poured on the floor, and ironed into it with a box-iron, heated from the interior by burning charcoal; it penetrates about a quarter of an inch into the wood. The excess of paraffin is scraped off, and the floor brushed with a hard brush; a little paraffin in turpentine is then put on and the flooring is good for years.

To meet the necessity of an impervious and hygienic floor, which, whilst embodying the appearance and advantages of a marble floor, is as warm as the ordinary wood floor, a large number of patent sawdust and cement mixtures are now on the market. A good type of this kind of floor is "doloment," which consists of two layers. The lower is an insulating composition of cork, asbestos, india-rubber, &c., and the upper is a polished, warm, and decorative layer unaffected by acids. Dolement is tough and well adapted for wards and operating-theatres, as it does not wear into dust. It can be conveniently nailed or glued down as in the case of kamptulicon.

The material best adapted for the wall surfaces of a ward is perhaps one of the most difficult problems in hospital construction. Various means have been taken to secure a truly impervious surface; the best material is, perhaps, fine plaster, coated with "velure" or "ripolin" both of which are enamel paints, which can be washed as often as desired, but equally good results can be obtained by the use of glazed tiles and other similar products. To facilitate cleaning, and to prevent stagnation of air, it is advisable to round the angles formed at the junction of the wall with the ceiling and wall with floor and the vertical angles of the walls.

The various forms of wards which have been adopted in hospitals are connected with the period in which the hospital was built. Since the pavilion system has become that now almost universally adopted, cross ventilated single wards are generally used. In it the windows face each other at equal distances on each side of the ward, while the beds

are arranged in two rows. A satisfactory type of ward is shown in Fig. 64.

Circular wards for hospitals have been advocated, the advantages claimed for them being :—(1) freedom of frontage to all points of the compass, and consequently greater accessibility to both light and air ; (2) greater area within a given length of wall ; (3) greater facilities for administration and cleanliness. Circular wards now exist both in this country and on the Continent, notably at Antwerp, Gravesend, Burnley, Liverpool, and Greenwich. The differences between one circular ward and another lie mainly in the mode of attachment to the central or main building and in the treatment of the central part. In some the rooms on either side of the corridor of approach abut on the circle, while in others the attachment is by a corridor only. At Burnley a staircase to the roof occupies the central part, while at Liverpool and Greenwich the central portion is occupied by stoves with smoke and ventilating shafts. At the Johns Hopkins Hospital at Baltimore two octagonal wards are conveniently arranged so as to allow free access of air and light to the adjoining pavilions ; it was also found that if the ordinary rectangular ward was selected for the site, it would have come too close to the nurses' home.

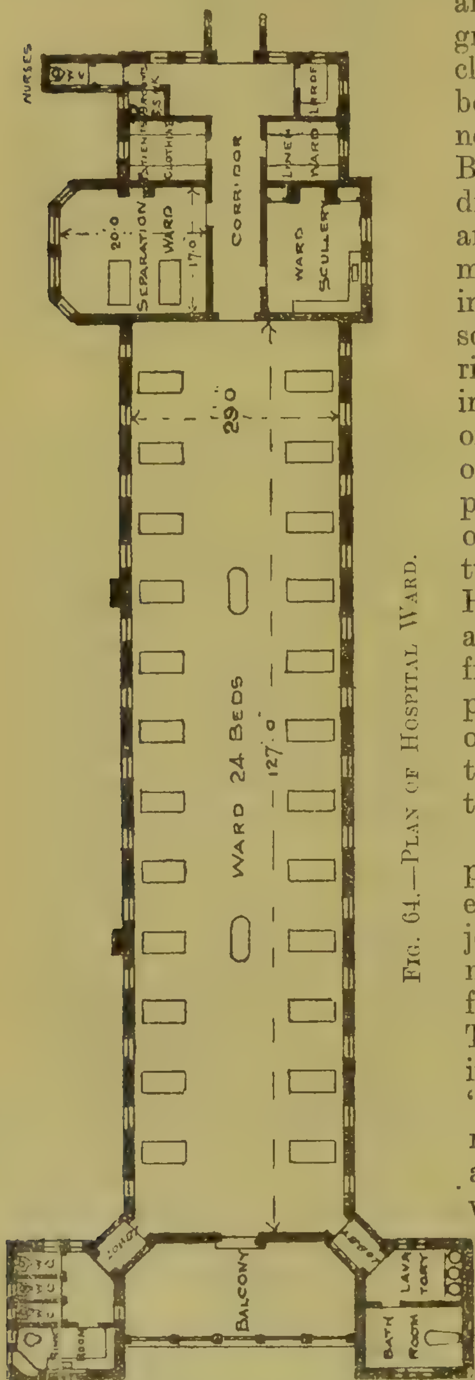


Fig. 64.—Plan of Hospital Ward.

Bathrooms and lavatories are generally placed for the purposes of convenience and economy with the water-closets in the projecting wings. The same necessity does not, however, exist for cutting them off from the ward by an intervening lobby. The floor of the bathroom should be of impervious material, preferably that called "mischiati." This is formed of cubes of marble laid close together, but without any attempt at regularity of pattern ; a lattice wooden standing-board should be placed over it. The bathroom and lavatory should be heated by hot-water pipes. Lavatory basins should be provided in the proportion of about one to every six patients.

Ward sculleries are usually attached to each ward, where the plates, &c., used by the patients are washed, and where simple articles of food are cooked. It should be provided with a small cooking range. A sink with hot and cold water laid on is also necessary.

The nurses' room is generally placed at the end of the ward, but not communicating directly into it ; it has, however, usually a small window looking into the ward. It was formerly used as a combined sitting-room

and bedroom. Under the modern system of nursing, where the duties are assigned for regular hours and where nurses are relieved in turn, there is no necessity for their sleeping near the wards, nor is it advisable that they should do so. This room can hardly be considered absolutely necessary in a modern well-ordered hospital.

Operating-room.—In all hospitals where surgical cases are received, a special room must be set apart where operations are performed. It must be within easy access of the wards, yet completely severed from aerial contact with them; neither must there be any connection with the kitchen, laundry, or mortuary. The best position is in a separate wing connected to the main corridor by an intercepting lobby, and so situated with relation to adjoining buildings that it is not overshadowed or overlooked by them. It should be so placed as to have free access of light, preferably from the north. In its construction everything of an absorbent nature should, as far as possible, be eliminated.

The floor is best made of "mischiati" mosaic laid on concrete, and may be finished with a slight fall to the external wall, where an iron pipe will carry away the water used for washing purposes. The walls up to a height of 7 feet are best lined with marble; above this they may be finished with fine plaster and cement, which, with the ceiling, should be painted and varnished. The tops of sinks and basins, and the shelves, should be made of glass, which is not only impervious but enables dust or dirt to be easily seen. The windows should be made flush with the wall and made to open for the purposes of ventilation; they should be glazed with plate-glass and be very large. The room should be heated with hot-water coils. Both hot and cold water should be supplied for the basins and cold water for the sink. Fresh-air inlets should be provided, and in some cases it may be advisable to filter the incoming air through cotton-wool. Outlet shafts with an opening into them near the floor of the room should also be provided. In large hospitals it is desirable to provide also a room for the administration of anæsthetics.

The *Out-patient Department* should be on one floor only, and entirely detached from the main buildings of a hospital. It should consist of a spacious and well-ventilated waiting-hall; a sufficient number of consulting-rooms readily accessible from the waiting-room; a dispensary with small waiting-room attached, so placed that patients do not have to re-enter the main waiting-hall after they leave the consulting-room; water-closets and lavatories for both males and females.

The *Mortuary* should be a detached building and single storey where possible. In the case of a crowded site, it may be conveniently placed at the top of a building, communication thereto being made by an outside staircase and lift. The mortuary should include, besides the room where several dead bodies may be placed at one time, a small room where one body can be separately viewed by friends.

Attached to the dead-house, but having no communication with the inspection room, should be a *post-mortem* room. This must be top-lighted, with a floor of some impervious material, made to fall to a channel under the table. The walls should be lined with glazed bricks or tiles, the table should be of marble on an iron frame, and the shelves should be of the same material. A large and deep sink must be provided, and the waste-pipe therefrom treated in the same way as a soil-pipe. An efficient trap must be placed immediately under the sink, and the pipe taken out through the wall into a vertical pipe, which must be carried up in full diameter as a ventilator.

Non-infectious Special Hospitals.—Although in all matters of structural hygiene these hospitals require the same care as the ordinary hospitals, still, in addition, they present some special needs. Thus, ophthalmic hospitals need the removal of sharp angles in wards against which blind or partially blind persons may accidentally injure themselves, and the provision of hand-rails on both sides of staircases. Open fireplaces are a mistake in these hospitals, as often the flickering flame of a fire is both trying and injurious to diseased eyes. Consumption hospitals require special warming and ventilation arrangements for their inmates, as well as liberal provision for those able to get up and move about. The sanatoria now so largely used for the treatment of the tuberculous present greater difficulties, both in location and planning. The essentials are the selection of a dry, sheltered site with a southern aspect and adequate arrangements for the permanent residence of the sick in the open air, without undue exposure to rain, wind and other viscissitudes of weather. It is desirable that in these buildings too much expenditure be not made on architectural features, but that all available funds be directed to the securing of reasonable comfort for the occupants consistent with the open-air treatment. The most prominent need in all children's hospitals is an isolation ward, as young children are extremely susceptible to infectious diseases. Convalescent hospitals are more properly homes for those recovering from acute illness, rather than mere hospitals for the sick. In the same way, cancer and incurable hospitals need to conform more to the freedom and independence of home life than to the more rigid arrangements of the institutions for treating acute cases. Lying-in hospitals, from the peculiar nature of the cases they receive, should be constructed with small rooms and not with large wards. Every such hospital should be provided with an isolation ward, absolutely distinct from the rest of the building.

Infectious Disease Hospitals.—These are quite a class by themselves; they may be either permanent or temporary buildings. It is, as a rule, undesirable to select any site for an isolation or infectious hospital which is less than some two acres in extent, and even then regard should be had to the need for extension of hospital buildings, whether for temporary purposes or owing to increase of population. Moreover, in determining the locality where such a hospital should be placed, the wholesomeness of the site, the character of the approaches, together with the facilities for water-supply and for slop and refuse removal, are matters of primary importance.

Sites for hospitals designed to receive small-pox require a very much larger space about them than sites for other infectious diseases hospitals. Small-pox hospitals are apt to disseminate the disease, and their sites should therefore be placed outside towns, and should indeed be sought at places as far distant from any populous neighbourhood as considerations of accessibility permit. The Local Government Board have suggested that, with a view of lessening the risk of infection, a Local Authority should not contemplate the erection of a small-pox hospital—

(1) On any site where it would have within a quarter of a mile of it as a centre either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150–200 persons.

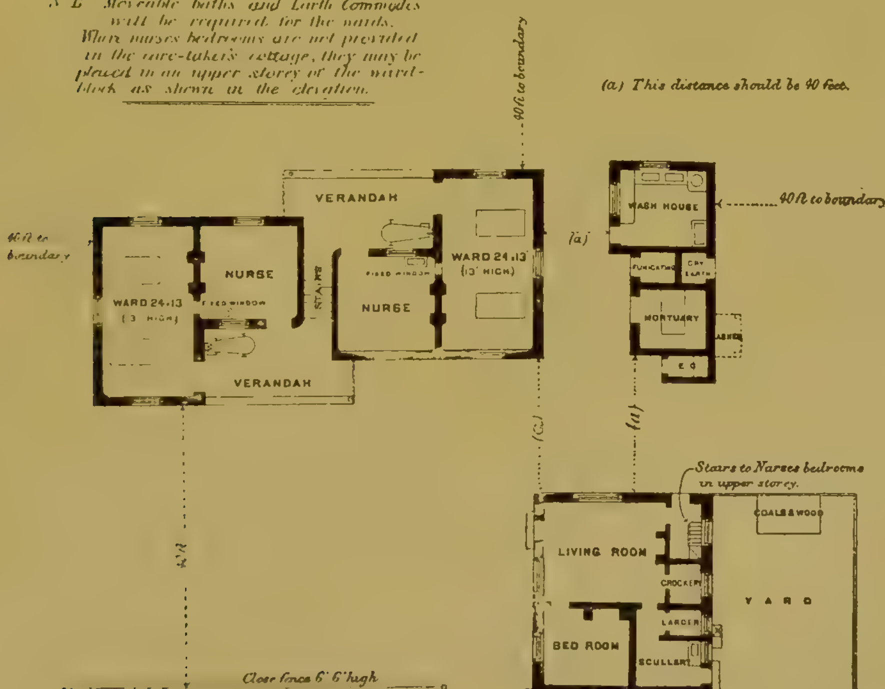
(2) On any site where it would have within half a mile of it as a centre a population of 500–600 persons whether in one or more institutions or in dwelling-houses.

It must also be understood that, even when the above conditions are

PLATE VII

ELEVATION.

N B Moveable baths and Earth Commodes will be required for the wards. When nurses bedrooms are not provided in the care-taker's cottage, they may be placed in an upper storey of the ward-block as shown in the elevation.



PLAN.

Scale 16 F' to one inch

strictly fulfilled, there may be circumstances under which the erection of a small-pox hospital should not be contemplated. Cases in which there is any considerable collection of inhabitants just beyond the half-mile zone should always call for especial consideration.

It has been suggested that small-pox hospitals may be so constructed as not to be dangerous to neighbouring habitations ; and that this can be done by a system of passing through a furnace all outgoing air from infected wards and places. But, thus far, the efforts made in this direction cannot be regarded as having successfully attained the end in view. More promising, however, is the system suggested by Key and Henman, whereby the outgoing air is made to pass through canvas screens, and in so passing is exposed to the action of a disinfectant.

Reference has already been made to the need, in isolation hospitals, of greater cubic space and ventilation. Owing to the remarkable tendency to aerial spread of infection in the diseases taken to infectious hospitals, the communication with the outside world has in them to be kept under the strictest control and each disease isolated separately, and kept, if possible, in separate blocks or buildings, the communication between which should be absolutely forbidden. Each block, besides wards, closets, bathrooms, and sinks, should have linen-, store-, and fuel-rooms, as well as a nurses' room. The disinfecting chamber, mortuary, and stables for ambulances and horses should also be clearly disconnected from all other parts of the building.

Considerable controversy has taken place as to whether infectious hospitals should be permanent buildings or merely temporary ones. The truth probably lies in the view that all administrative arrangements, and a certain limited accommodation for the infectious sick, should be in permanent buildings, which, existing thus ready to hand in non-epidemic times, can be quickly supplemented by additional wards in either huts or tents within a few days, in case of widespread epidemics. Some means of isolation are needed in every community at all times, and it is a sounder policy to be able to delay and prevent epidemic outbreaks by isolating the first few sporadic cases as they occur, in a small but permanent infectious hospital, than to have to grapple with epidemics already in full existence by means of hastily constructed, and often expensive, temporary structures. Many materials have been suggested for the construction of these temporary buildings, more particularly wood, galvanised iron, canvas, and waterproof paper. Although they are comparatively cheap and rapidly erected, temporary hospitals should never be regarded as able to supersede permanent buildings of brick or stone ; their true use is to supplement, not to supersede. Moreover, they are extremely difficult to ventilate, and to warm in winter or to cool in summer. Their durability is small, and their proper disinfection is almost impossible. Of course they can be burnt when done with ; but if epidemics of infectious disease rapidly succeed each other, the renewals of temporary hospital buildings will soon exceed in cost that of structures of a more permanent nature. As infectious hospitals, unlike the great bulk of general and special hospitals, are in no sense charitable institutions, but really public buildings provided and supported by rates, the true bearing and merits of the question whether these hospitals should be temporary or permanent buildings is one which intimately concerns the interests of every citizen.

The extent of hospital accommodation which it is necessary or desirable to provide must depend upon the population and other conditions peculiar to the district it has to serve. Whatever may be the amount of

accommodation to be provided, the general principles of arrangement will remain the same. In a memorandum on the provision of Isolation Hospital Accommodation by Local Authorities, the Local Government Board have pointed out that large villages and groups of adjacent villages will commonly require the same sort of provisions as towns. "Where good roads and proper arrangements for the conveyance of the sick have been provided, the best arrangement for village populations is by a small building accessible from several villages; otherwise the requisite accommodation for (say) four cases of infectious disease in a village may at times be got in a fairly isolated and otherwise suitable four-room or six-room cottage which has been acquired by the authority; or by arrangement made beforehand with some trustworthy cottage-holders, not having children, that they should receive and nurse, on occasion, patients requiring such accommodation."

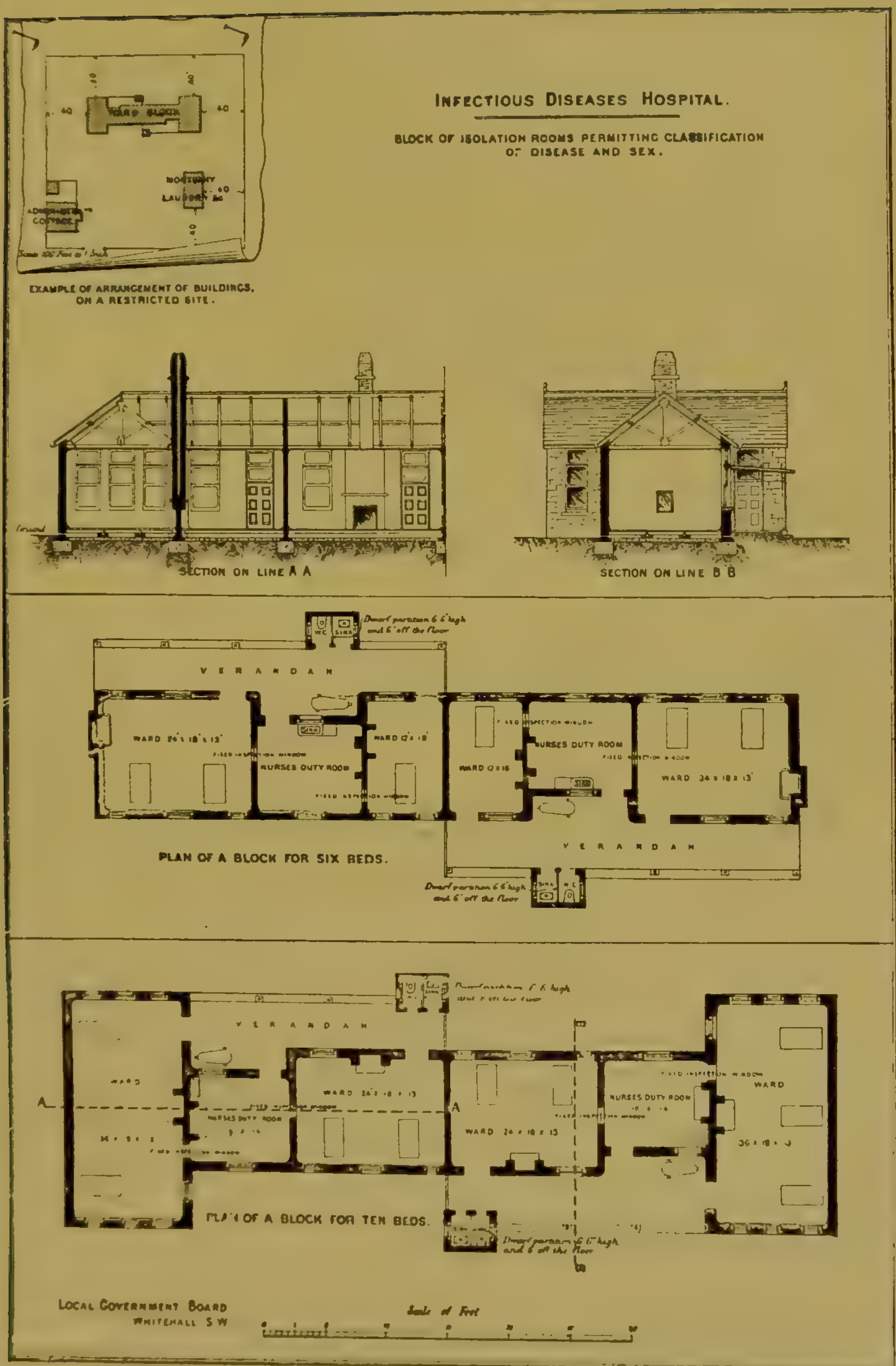
"In towns, hospital accommodation for infectious diseases is wanted more constantly, as well as in larger amount than in villages; and in towns there is greater probability that room will be wanted at the same time for two or more infectious diseases which have to be treated separately. The permanent provision to be made in a town should consist of not less than four rooms in two separate pairs; each pair to receive the sufferers from one infectious disease, men and women of course separately. The number of cases for which permanent provision should be made must depend upon various considerations, among which the size and the growth of the town, the housing and habits of its population, and the traffic of the town with other places, are the most important. There is no fixed standard, therefore, by which the standing hospital requirements proper for a town can be measured. Furthermore, it is to be remembered that occasions will arise (as where infection is brought into several parts of a town at one time) when isolation provision, in excess of that commonly sufficient for the town, will become needful."

"For a town the hospital provision ought to consist of wards in one or more permanent buildings, with space enough for the erection of other wards, temporary or permanent. Considerations of ultimate economy make it wise to have permanent buildings sufficient for somewhat more than the average necessities of the place, so that recourse to temporary extensions may less often be necessary. In any case it is well to make the administrative offices somewhat in excess of the wants of the permanent wards; because thus, at little additional first cost, they will be ready to serve, when occasion comes, for the wants of temporary extensions."

An isolation or infectious disease hospital, of whatever size, should consist of (1) a detached administrative block; (2) wards, with their offices in separate pavilions, or blocks, or cottages, at safe distances, providing for the separation of the sexes and for patients suffering from different diseases; (3) outhouses, such as laundry, stores, disinfecting apparatus, mortuary, &c.

The administrative block should minister to the whole hospital, except, perhaps, when small-pox is isolated. In these cases, nurses attending small-pox should be accommodated in rooms apart from the general administrative building. If obliged to sleep in the administrative building, they should change their clothes and take a bath on going off duty. No food, clothing, earthenware, furniture, &c., should get mixed in the work of administration. The block or ward used for one disease should be at least 40 feet from the ward occupied by patients suffering from any other disease. When a patient is admitted, he should be sent into the receiving room of the block set apart for his disease. If there is doubt as to the nature

PLATE VIII


INFECTIOUS DISEASES HOSPITAL.
BLOCK OF ISOLATION ROOMS PERMITTING CLASSIFICATION OF DISEASE AND SEX.
WARD BLOCK
MORTUARY LAUNDRY &c
EXAMPLE OF ARRANGEMENT OF BUILDINGS, ON A RESTRICTED SITE.
SECTION ON LINE A A
SECTION ON LINE B B
VERANDAH
NURSES DUTY ROOM
PLAN OF A BLOCK FOR SIX BEDS.
PLAN OF A BLOCK FOR TEN BEDS.
LOCAL GOVERNMENT BOARD
WHITEHALL S W
Scale of Feet

of the disease, he should be sent to an isolation ward until a diagnosis can be definitely made. If there is no doubt about the case, it should be sent to the ward intended for it. The patient, if able to bear it, should be undressed in the bathroom, bathed, provided with a clean night-dress, and put to bed. His own clothes should be put immediately into the disinfecting chamber. If necessary, they should be destroyed. All bedclothes, linen, towels, &c., in an infectious hospital should be marked separately for each disease, stored in its special department, and on no account used in any other part of the building. Care should be taken to prevent clothes becoming infected in the laundry. The clothes from each department should be thoroughly disinfected before being taken to the laundry. When dry, the clothes should at once be brought back and stored in their special department.

All spoons, knives, forks, feeding-cups, glass and earthenware should be of different patterns for each disease, or differently marked for each department, and washed and stored there. The main articles of food should be conveyed to each block in utensils belonging to the administrative block by a person not engaged in any of the wards, and then transferred into utensils belonging to that block. Nurses should keep to one disease exclusively when on duty.

The simplest type of isolation or infectious disease hospital is that shown in Plate VII., suggested by the Local Government Board. It must comprise three separate buildings:—(1) the administrative block, comprising accommodation for a caretaker, kitchen offices, and two or three rooms for nurses; or it may be simply a cottage containing a living-room and two or three bedrooms for the caretaker, with the kitchen offices; (2) a block for patients; and (3) the wash-house, mortuary, and disinfection chamber block.

The ward block shown on the same plan provides accommodation for two patients of each sex, with two nurses' ante-rooms on the ground floor, and their bedrooms above. The third block contains a mortuary, wash-house, and small disinfecting chamber. It will be obvious that such a hospital provides the smallest possible amount of accommodation, and contemplates the reception of patients suffering from one disease only.

In Plate VIII. a rather larger hospital building is shown, the plans and sections providing for six and ten patients. These may be regarded as typical isolation blocks in which patients of each sex, and suffering from two distinct diseases, can be treated. This block is the most important one, and whatever else is omitted this must always be provided. A convenient disposition of buildings upon the site is also indicated on the same sheet.

In Plate IX. is shown the plan and section of a small pavilion adapted to receive six male and six female patients suffering from one kind of infectious disease.

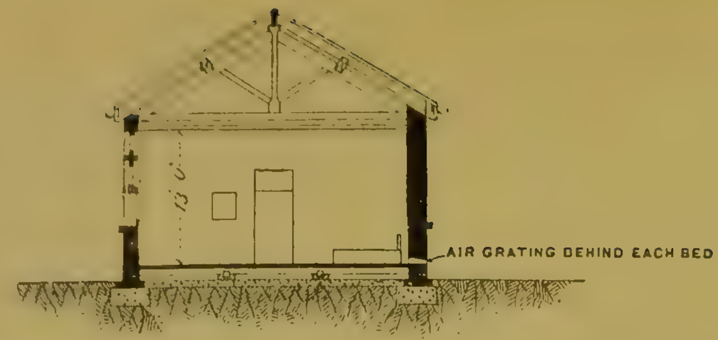
"It will be found that in all the plans proper standards of space are observed, namely, not less than 2000 cubic feet of air space, 144 square feet of floor space, and 12 linear feet of wall space to each bed; and that means are provided for the adequate ventilation and warming of wards, and for securing them from closet emanations and the like. In plan A, earth-closets, in other plans water-closets, are indicated as the means of excrement disposal. The latter are to be regarded as preferable where efficient sewers are available. Places for washing and disinfection, and for a mortuary, are indicated. It will be observed that an interval of 40 feet is everywhere interposed between every building used for the reception

of infected persons or things and the boundary of the hospital site. This boundary should have a close fence of not less than 6 feet 6 inches in height, and the 40 feet of interval should not afterwards be encroached on by any temporary building or extension of the hospital. In the construction and arrangement of such temporary buildings as may at times be wanted in extension of the permanent hospital, the same principles should be held in view."

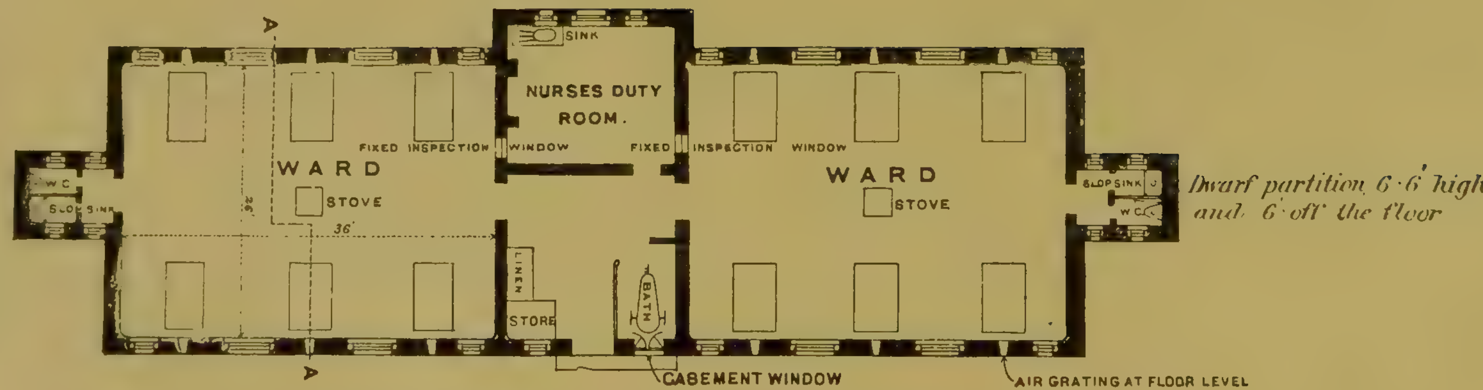
In all hospitals for infectious diseases provision must be made to prevent, if possible, the conveyance of infection to the outside world, either by patients on their discharge or by nurses or servants going outside the gates. For patients on their discharge a suite of three rooms communicating with each other should be arranged. The first room should be just sufficiently large for one person to undress in; in this room the patient leaves his or her infected clothing. The second or intermediate room is a bathroom. After bathing, the patient enters the third room, where he puts on a complete suit of clean, or preferably new, clothing. Having dressed, he should leave the building by a door leading directly into the open air, and should not again enter any part of the hospital buildings. For the staff, ample bathing accommodation should be provided; and, as far as possible, it should be made a rule that no one employed in the hospital wards should leave the grounds without having previously bathed. It is obvious that such a rule as this cannot be rigidly enforced, but, all the same, the means of complying with it should be provided, and its observance should be encouraged as far as possible.

The Utility of Isolation Hospitals.—This question has been much debated during recent years, and many persons have arrived at the conclusion that they are practically useless for preventing the spread of infection, whilst others who admit that some benefit accrues from their use allege that this benefit is not commensurate with the cost of erecting and maintaining them. The chief evidence in support of this hostile attitude towards isolation hospitals relates to scarlet fever, and we find that the allegations against scarlet fever hospitals may be classified under the following heads :—(1) That there has been no reduction of incidence and no reduction of scarlet fever death-rate from their use, even if the reverse is not the fact. (2) That the hospitals are dangerous in themselves to cases sent there, principally through the aggregation causing complications that might not occur elsewhere. (3) That return cases occur after discharge of cases from hospital. A critical study of the very voluminous literature which exists on this subject compels us to recognise that it is very difficult to demonstrate the precise effect of isolation hospitals, either upon scarlet fever or any other kindred disease, by means of statistics, which require a large amount of qualification before they can be of any value for comparative purposes. In respect of many of the statistics, upon which some of the most able attacks challenging the utility of these hospitals have been based, no attempt has been made to ascertain accurately what proportion of the notified cases were removed to hospital, at what period of their illness they were so removed, what were precisely the methods adopted for disinfecting the invaded houses, by whom this was done, and to what extent infective contacts were sought for. It is, of course, conceivable that in many instances the maximum opportunity for the spread of infection had been exercised before the case was recognised and isolated. With regard to the comparison of the same towns before and after practising isolation, the comparisons must be over longer periods than are yet available. The figures need to be expressed in rates per thousand children under fifteen years of age. It must also be borne in mind that the density of population, the proportion

PLATE IX



SECTION ON LINE A.A.



PLAN OF A WARD PAVILION FOR 12 BEDS.

of children attending elementary schools, are increasing, and tend to discount the beneficial effects of isolation. If an attempt is to be made to express in figures the effect of the isolation of scarlet fever or any other disease in special hospitals, the attack rate should not be expressed in terms of the entire population, the bulk of whom might, as far as the infection is concerned, be living a hundred miles away, but in terms of the population exposed to infection. Failure to recognise this lies at the bottom of the statistical arguments of the opponents of isolation hospitals. For these reasons, we are compelled to think that so far as mere statistics go, the case against isolation hospitals that they have brought about no reduction in incidence of scarlet fever is not proven. We fully admit that many of the exaggerated conceptions of those who were instrumental in nitiating the isolation hospital movement have not stood the test of experience; and the more we know about the natural history of the infectious diseases, the less difficulty do we have in understanding that many cases escape recognition and consequently notification. In these circumstances, it is hardly to be wondered at that there is a difficulty in demonstrating by statistics the value of isolation hospitals. We might go further and ask, is it wise to attempt to apply statistics to a problem of which none of the factors are constant? —a varying host, a varying parasite, and, in some instances, a varying age-grouping of the population.*

As to the other two allegations against these hospitals, namely, that they are dangerous in themselves to cases sent there, and contributory to the occurrence of return cases, we venture to suggest that there is here a confusion of thought regarding the principle and the practice of isolation hospitals. Even if these allegations be true, they do not traverse the principle which suggests the need of a hospital of this kind, they indicate merely that there is something radically wrong in the administration and practice of these institutions. Here the critics of isolation hospitals are on safer ground, for there is much room for improvement in both administration and practice. Many of these hospitals are inadequate both in respect of size and arrangement. Few are competently staffed, and many of them are looked upon as having served their purpose when they have removed the disease from the community. So far from these hospitals having had their day, we think that the adverse criticism of recent years, by drawing attention to defects in management, will bring about an improvement in administrative detail; and, as time and experience bring improved methods of treatment and an increased faith in its benefits, there can but result an extension and not a diminution of hospital isolation. We are disposed to think that the best results will follow the development and extension of the cubicle system for the isolation of incoming patients and preventing the introduction and spread of secondary infection, also preventing the trouble arising from errors in diagnosis. The newly initiated policy of the Metropolitan Asylums Board on these lines will be watched with interest.† The practice now recommended and contemplated will facilitate separate isolation of cases at once on admission with a view to further observation and classification; further, that after a probationary period of a fortnight or three weeks in the admission cubicles, uncomplicated cases may be transferred to general wards as is now the practice, but that the complicated cases should remain either in the cubicles until they had recovered or, if convenient, they might be transferred to specially reserved wards.

* The reader may consult with advantage a paper by Newsholme, "The Utility of Isolation Hospitals in Diminishing the Spread of Scarlet Fever," *Journal of Hygiene*, vol. i. p. 145.

† *See* an interesting paper on "Isolation in Fever Hospitals" by T. W. Aldwinckle, *Journ. Roy. San. Institute*, October 1906, p. 502.

LAW RELATING TO STREETS, DWELLINGS AND UNHEALTHY AREAS.

A vast amount of legislation controls the varied interests connected with these matters, and embraces the consideration of such details as new streets, buildings, tenement-houses, common lodging-houses, cellar dwellings, canal-boats, movable dwellings other than canal-boats, lodgings and houses for the working classes, and the removal or amendment of what are deemed to be unhealthy areas. The law relating to these diverse topics is scattered through a number of legal enactments, and sadly needs codification into one Act. In the following summary, an attempt has been made to make clear the essential facts in respect of each subject.

NEW STREETS AND BUILDINGS.

The Public Health Act, 1875, and the Amendment Act, 1890, give, so far as relates to **England and Wales**, Sanitary Authorities, especially urban authorities and such rural authorities as have obtained urban powers, considerable control over the arrangements, construction, and planning of streets and buildings within their districts.

By the Act of 1875 all public streets in urban districts are vested in the Sanitary Authority, who must cause them to be levelled, paved, and repaired as occasion may require (section 149). All owners of property abutting on any private street or part of a street may be required by an urban authority to level, pave, sewer, light, or make good such street or part of a street, and in case of default the Sanitary Authority may carry out the work and recover expenses from the owners according to the frontage of their respective premises (section 150). Section 157 of the same Act enables every urban authority to make bye-laws with respect to the structure of walls, foundations, roofs, and chimneys of new buildings for securing stability and the prevention of fires, and for purposes of health, and with respect to the sufficiency of the space about buildings to secure a free circulation of air, and with respect to the ventilation of buildings. For the purposes of the Act, the re-erection of any building pulled down to or below the ground floor, or the conversion into a dwelling-house of any building not originally constructed for human habitation, or the conversion into more than one dwelling-house of a building originally constructed as one dwelling-house only, shall be considered the erection of a new building.

These powers have been extended by section 23 of the Public Health Acts Amendment Act, 1890, so as to enable any urban Sanitary Authority to make further bye-laws concerning new buildings upon the following points:—(*a*) adequate water-supply to closets; (*b*) construction of floors, hearths, and staircases; (*c*) height of rooms intended for habitation; (*d*) paving of yards and open spaces in connection with houses; (*e*) provision of secondary approaches to houses, for the purpose of removing refuse. It is further provided that bye-laws respecting closets and drainage may be made applicable to old as well as new houses. Similar power of framing and enforcing bye-laws for each of the above purposes, with the exception of the prevention of fires, has been given to rural authorities adopting Part III. of the Act. Apart from this, however, the Local Government Board can, as already stated, grant full urban powers to rural authorities. This same section 23 enables any Sanitary Authority to make bye-laws to

prevent buildings erected in accordance with bye-laws from being altered in such way that if at first so constructed they would have contravened the bye-laws.

Other sections of the same Act of 1890 (sections 24 and 25) prohibit any new building being erected upon ground impregnated with animal or vegetable matter, or upon which such matter has been deposited, unless such matter has been properly removed or has become innocuous. Similarly, if in an urban district, any portion of a room is immediately over any privy (not being a water-closet or earth-closet), cesspool, midden, or ashpit, it is illegal to occupy it, or suffer it to be occupied, as a dwelling-place, sleeping-place, workroom, or place of business. Another enactment is, that buildings described in deposited plans otherwise than as dwelling-houses must not be used as such, under a penalty not exceeding £5, and a daily penalty not exceeding 40*s*. (section 33). These provisions are, however, subject to the exception, that if the building has in rear thereof, and adjoining and exclusively belonging thereto, such an open space as is required by Act of Parliament or bye-law for the time being in force with respect to buildings intended to be used as dwelling-houses, and if such part of the building as is intended to be used as a dwelling-house has undergone such structural alterations as, in the opinion of the Sanitary Authority, render it fit for that purpose.

Further, an urban Sanitary Authority, if satisfied that any building or wall is in a ruinous state so as to be dangerous to passengers or to the inmates of neighbouring houses, shall cause a fence to be put up, and shall order the owner forthwith to secure or pull down such building; and in default thereof the surveyor may obtain a justice's order to carry out the necessary works, and may recover the expenses. The authority may also compel the owner of any building adjoining or near to a street to provide within seven days efficient eaves-gutters and rain-pipes (Towns Improvement Clauses Act, sections 74 to 78; Public Health Act, 1875, section 160).

For the guidance of Sanitary Authorities in framing bye-laws in respect of new streets and buildings, the Local Government Board have issued Model Bye-laws; of these models the following is a summary:—

(*a*) No new street must be less than 36 feet wide, if it exceeds 100 feet in length or is intended to be a carriage road; nor less than 24 feet in any case. One end at least must be quite open. (*b*) No buildings must be erected upon soil polluted with animal or vegetable matter. Sites in low and damp situations, near rivers or in excavations must be elevated artificially. The site of a new house must be entirely asphalted or covered with 6 inches of concrete. (*c*) Walls of all new buildings must be constructed of good bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together with good mortar compounded of good lime and clean sharp sand or other suitable material, or with good cement, or with good cement mixed with clean sharp sand. Every wall must have a proper damp course of durable and impervious material beneath the level of the lowest timbers, and at least 6 inches above the ground. If the ground is to be in contact with a wall above the level of the floor of the lowest storey, that wall must be made double, with a cavity 2½ inches wide extending from the base of the wall to 6 inches above the surface of the adjoining ground; and damp courses must be inserted both at the base of the wall and at the level of the top of the cavity. The minimum thickness of the wall of a new house should be as follows:—Where a wall is not over 25 feet in height, if it does not exceed 35 feet in length, and does not comprise more than two storeys, it shall be 9 inches for its full height; but if it do comprise more than two storeys, or exceed 35 feet in length, it shall be 13½ inches below the topmost storey, and 9 inches for the rest. Where walls are over 25 feet high, and not exceeding 35 feet in length, they should be 13½ inches thick below the topmost storey, and 9 inches for the rest; but if they be longer than 35 feet, then they must be 18 inches thick for the height of one storey, then 13½ inches thick for the rest of the height below the topmost storey, and 9 inches thick for the rest of its height. Walls over 35 feet high must be 18 inches thick for the first two storeys, and 13½ inches for the rest. If over 50 feet in height, walls should be 22 inches thick for the height of one storey, then 18 inches for the next two storeys, and finally 13½ for the rest of the height. Party-walls must be carried up at least 15 inches above the roof, the distance to be measured at right angles to

the slope of the roof. (*d*) Roofs must be made of incombustible materials, and provided with gutters leading to rain-pipes. (*e*) A new house must have along its whole frontage an open space measuring at least 24 feet to the boundary of any land or premises immediately opposite or to the opposite side of the street. In the rear there must be an open space exclusively belonging to the house, at least 150 square feet in area, and free from any erection above the ground level, except a closet and an ashpit; the open space must extend along the entire width of the house, and must measure in no case less than 10 feet from every part of the back wall of the house; if the house is 15 feet high, the distance must be 15 feet; if 25 feet, then 20 feet; and if 35 feet or more, then 25 feet at least. (*f*) If the floor of the lowest storey is boarded, there must be a clear space of at least 3 inches between the boards and the impervious covering of the site, and the space must be ventilated. (*g*) Every habitable room must be provided with windows opening directly into the external air. The window area must be at least one-tenth of the floor area; at least half of each window must be made to open, and it must open at the top. Every habitable room must, further, either have a fireplace and chimney or a special ventilating aperture or air-shaft with an unobstructed sectional area of at least 100 square inches. Every new building must be provided with adequate means of ventilation, and to secure this, so far as dwelling-rooms in general are concerned, the minimum height should be 9 feet in every part, except in attics used as bedrooms, when a minimum height of 5 feet is permitted, if in two-thirds of the area the height is not less than 9 feet.

The same Model Bye-laws proceed to suggest that (*h*) the Sanitary Authority may, under certificate from the Medical Officer of Health or Surveyor, declare any building or part of a building erected after . . . unfit for habitation, and order it to be closed until rendered fit for habitation. Opportunity must be given to the owner to show cause why such order should not be made. (*i*) Plans and sections must be submitted showing in detail the construction of all proposed new streets or buildings. (The authority must signify their approval or disapproval within a month after receiving them, by section 158, Public Health Act, 1875.) (*j*) Notice must be given to the surveyor of the dates upon which any sewer, drain, or foundation is to be covered up; notice must also be given of the completion of the work; while free access for inspection must be afforded to him at all times during the progress of the work. (*k*) If any work to which the bye-laws apply is done in contravention of such bye-laws, the Sanitary Authority are empowered to remove, alter, or pull down such work.

In London, the control, regulation, and management of all matters relating to the planning and laying out of new streets and the constructing of new buildings is governed, save in respect of certain matters in connection with the City of London, by the provisions of The London Building Act, 1894. This Act consolidates and amends the previous Metropolitan Building Acts, and also certain provisions relating to the formation and widening of streets, the lines of building frontage, dwelling-houses on low-lying lands, sky-signs, and the naming and numbering of streets, most of which provisions were formerly included in the various Metropolis Management Acts and General Powers Acts of the London County Council. The Act is not, in itself, an absolutely complete code regulating building operations in London, as it is still necessary to refer to existing enactments of the Management Acts for provisions as to drainage of houses, as to the construction of vaults and cellars under streets, and as to the erection of hoardings during building. The sanitary arrangements of houses, the construction of underground rooms, and the structure of premises in which any offensive business is carried on, are regulated by the Public Health (London) Act, 1891, and the bye-laws in force thereunder; and in the City of London, such jurisdiction as was exercisable by the Commissioners of Sewers, under the Sewers Acts previous to the passing of this 1894 Act, still remains in force.

The City Corporation are the Local Authority within the city for the purposes of this Act, but the city is expressly exempted from certain provisions of the Act; these are sections 9 (4) and (5), 11 (4) and (5), 22 to 31, 84, 164 in part, 165, and 199, whereby the Corporation retain jurisdiction, within the city, over the altering and planning of streets, lines of frontage, the erection of hoardings, dangerous structures, and sky-signs, the placing of lamps, signs, or other structures overhanging the public way, the making of bye-laws with respect to sites and foundations,

prevention of fires, the materials of walls, and duties of district surveyors in relation to general house construction. In respect of these matters, the City Corporation hold special powers under the Metropolitan Building Acts, 1855 to 1882, and the City of London Sewers Acts, 1848 and 1851; but, as already stated, with these exceptions the provisions of the London Building Act, 1894, apply within the City of London as in other parts of the metropolis, the Corporation being the Local Authority under the Act.

A considerable advance upon the previous legislation affecting London has been made, in the power given to the County Council to increase the width of certain new streets, not within two miles of St. Paul's Cathedral, from 40 to 60 feet (section 12), and to refuse, if they think fit, to sanction plans for streets formed for carriage traffic of less width than 40 feet clear, and those formed for foot traffic less than 20 feet clear (section 9). Similarly, no new buildings shall be erected with reference to streets intended for carriage traffic or with reference to footways, unless their external wall, fence, or boundary be at least 20 and 10 feet respectively from the centre of such street or footway (section 13). Sections 22 to 31, which do not apply to the city, empower the County Council under certain conditions to move back buildings which project, and to prevent any new buildings being erected so as to project beyond the frontage line of the street. Part V. of the Act, or sections 39 to 52, contains provisions with reference to open spaces about buildings, which are a great advance upon any previously existing law. The application of the principle of measurement by angles (section 41) for the purpose of determining the height, in relation to the space required at the rear of houses, is novel, so far as regards London, though it has been in operation in Liverpool under bye-laws framed with the sanction of the Local Government Board. Every domestic building (that is, a building which is neither a public building nor of the warehouse class) abutting upon streets formed or laid out after January 1, 1895, must have an open space of an aggregate extent of not less than 150 square feet in its rear, and exclusively belonging thereto; this space must extend throughout the entire width of the building, and be at least 10 feet in depth in every part. This open space must be free from any erection thereon above the level of the adjoining pavement, except a water-closet, earth-closet, or privy, and a receptacle for ashes, and enclosing walls, none of which erections shall exceed 9 feet in height. The building itself may be erected to a height equal to twice the width of the open space provided at the rear of the building, but an increase of height is allowed in cases where there is a street or permanent open space in the rear of the building. This result is obtained by confining, except as in the section provided, the height of a building within an imaginary diagonal line, to be drawn at an angle of $63\frac{1}{2}^\circ$ from an imaginary horizontal line drawn at right angles to the roadway, and at the level of the pavement in front of the centre of the building. The point in the horizontal, from which the diagonal springs, will be the intersection of the horizontal line with the rear boundary of the open space, except where the boundary of such space is not parallel with the rear wall of the building.

In the case of certain corner buildings, the space in the rear may be occupied by buildings not exceeding 30 feet in height, and the return front of such buildings may be carried up to the full height of the front elevation.

As regards buildings abutting upon a street formed or laid out before the commencement of the Act, the height of such buildings, in relation to the open space required at the rear, will be determined by the same method of drawing diagonal and horizontal lines as provided above, except

that the horizontal line may be drawn at a level of 16 feet above the level of the adjoining pavement; and the required open space, except in the case of working-class dwellings, may be above the level of the ceiling of the ground-floor storey, or above a level of 16 feet above the pavement. Certain savings for domestic buildings on old sites, when evidenced by plans certified by the district surveyor, and a provision for cases when an area is cleared of existing buildings, and new streets laid out thereon, are provided by sections 43 and 44. Special provision is made by section 45 for providing adequate light and ventilation for courts constructed within buildings, and for habitable rooms looking on to such courts. If the depth of such court from the eaves to the ceiling of the ground storey exceeds the length or breadth of the court, adequate provision for ventilation must be made by means of a communication between the lower end of the court and the outer air. No habitable room, without a window directly opening into the outer air, otherwise than into a court enclosed on every side, shall be constructed in any building unless the width of such court, measured from such window to the opposite wall, shall be equal to half the height measured from the sill of such window to the eaves or top of the opposite wall. The general limit of the height of buildings is fixed at 80 feet (sections 47 to 52). All matters relating to the provision of open spaces about buildings, and the height of buildings, are subject to the supervision of the district surveyor (section 138). Every new building exceeding 60 feet in height must be provided, on the storeys the upper surface of the floor whereof is above 60 feet from the street level, with such means of escape in the case of fire as can be reasonably required under the circumstances of the case; and no storeys of such buildings may be occupied until certified by the Council that these provisions have been complied with (section 63). No building may be built nearer than 50 feet to any other building used for dangerous and noxious businesses, such as match factories, turpentine, varnish, tar, resin, or Brunswick black manufactories, blood- and bone-boilers, soap-boilers, tallow-melters, fellmongers, tripe-boilers, and slaughter-houses for cattle or horses (sections 118 to 121). Similarly, no building may be erected upon land of which the surface is below the level of Trinity high-water mark, and which is so situate as not to admit of being drained by gravitation into an existing sewer, except with the permission of the County Council (sections 122 to 124). The first schedule of the Act gives elaborate tables as to the permissible limits for the thicknesses of walls, proportionate to height; these in the main follow the general rules already given in the Model Bye-laws of the Local Government Board, but are more comprehensive.

Before closing this necessarily brief reference to this important London Building Act, 1894, it may be convenient to state specifically that the Statutes, other than this Act of 1894, which are still in force, and which affect building operations in the metropolis, especially in the city, are:—The Act for Better Paving, Improving, and Regulating the Streets of the Metropolis, &c., commonly known as 57 Geo. III. cap. xxix.; the Metropolis Management Act, 1855, sections 73 to 123, 202 to 204, 211, 212, 227, 231, 242, 247, and 250; the Metropolis Management Amendment Act, 1862, sections 47, 48, 49, 61, 63 to 65, 68, 69, 88, 96, 97, 102, 104 to 107, and 110 to 112; the Metropolis Management Buildings Acts Amendment Act of 1878, Parts I. and III.; the Metropolis Board of Works Act, 1882, sections 1, 3, 45, and 48; the Metropolis Management Amendment Act, 1890; the London Council (General Powers) Act, 1890, sections 1, 2, 32, 39, 40, and 41; the Factory and Workshop Act, 1891, sections 7 and 41; the

Public Health (London) Act, 1891; and the City of London Sewers Acts of 1848 and 1851.

In Scotland.—By the Local Government (Scotland) Act, 1895, section 9, in the rural or landward districts, the County Councils have powers to make bye-laws for regulating the erection and construction of new buildings. The section is based upon sections 157–8–9 of the English Public Health Act, 1875. It contains a drastic and advanced definition clause whereby "any alteration of the structure of any house" brings it within the category of a "new house." The wording of the sub-sections dealing with the purposes for which bye-laws may be made follows the lead of the English Act in failing to distinguish in these instances between new and existing houses. Apart from powers under the Act of 1895, local authorities can deal with any defects in respect of buildings as nuisances under the Public Health (Scotland) Act, 1897, or under the Housing of the Working Classes Act, 1890.

In the rural or landward districts the local authorities have practically no powers of supervision over the construction and general arrangements of new dwellings; but they can, as already intimated, deal with any defects in these respects as nuisances under the Public Health (Scotland) Act, 1897, or under the Housing of the Working Classes Act, 1890.

In the burghs, the Burghal Commissioners have elaborate powers under the Burgh Police (Scotland) Act, 1892, sections 166–180, 201–209, and the Public Health (Scotland) Act, 1897. Some of the provisions are embodied in the former Act, while others appear as rules in the schedules. The chief distinctive provisions are that (*a*) all rooms in new or altered dwelling-houses must be sufficiently lighted and ventilated from the street, or from an open space equal to three-fourths of the area in which the house stands. (*b*) Not more than twelve flat tenements may open from an inside stair, nor more than twenty-four from an outside stair. (*c*) In new dwellings, rooms on the ground floor must be 9½ feet in height, and on other floors 9 feet, except attics, which must be 8 feet high over one-third of their area, and nowhere less than 3 feet. (*d*) Every new habitable room of less area than 100 feet, built without a fireplace, must have special means of ventilation. There are further provisions as to ventilation of common stairs, and for the prohibition of the erection of any building upon polluted sites.

In burghs, where there is a Dean of Guild Court, this body is practically a committee of the Burghal Commissioners, and discharges all the functions in respect of buildings.

In Ireland.—Under section 41 of the Irish Public Health Act of 1878, urban and rural Sanitary Authorities have very similar powers for making bye-laws, and in respect of the same matters as have the English urban authorities under section 157 of the Act of 1875. Any bye-laws made under this section 41 are not applicable to buildings erected before August 8, 1878. Although section 23 of the Public Health Amendment Act of 1890 extends to Ireland, its general application is little called for, as sections 41 and 42 of the Irish Act of 1878 apply to both rural and urban Authorities, thus differing from sections 157 and 158 of the English Act of 1875, which apply only to urban authorities. Sections 25 and 33 of the Amendment Act, 1890, may be applied to rural and urban districts, and section 24 to urban districts in Ireland as well as in England. Section 36 provides that all buildings, being places of public resort in urban districts, must have proper means of egress and ingress; while in towns constituted under the Towns Improvement (Ireland) Act, 1854, the Town Commissioners have full control over the erection and planning of all places of public entertainment.

COMMON LODGING-HOUSES.

While the Public Health Act, 1875, which, so far as relates to **England and Wales,** does not give any definition of the expression "common lodging-house," it is commonly taken to mean, for the purposes of the Act, those lodging-houses "in which persons of the poorer class are received for short periods, and, though strangers to each other, are allowed to inhabit one common room." The term does not cover rooms common to the members of one family or household, nor inns, nor lodgings let to the middle or upper classes.

Section 76 of the Act requires every urban and rural Sanitary Authority to keep a register of common lodging-houses in their district, in which shall be entered the names and residences of the keepers thereof, and the situation of every such house, and the number of persons authorised by such authority to be received therein. It is unlawful to keep a common lodging-house unless it is registered (section 77), and this can only be done after it has been inspected and approved for the purpose by some officer of the Sanitary Authority (section 78). If required, the notice of registration must be affixed to the house (section 79).

Before any premises are approved as suitable for a common lodging-house they should—

"(1) Possess the conditions of wholesomeness needed for dwelling-houses in general; and (2) should have arrangements fitting it for its special purpose of receiving a number of lodgers." Thus, the house should have dry foundations, and have proper drainage, guttering, and spouting, with a well-laid and paved yard abutting on it. The drains must be properly connected, the soil-pipe ventilated, the water-closets trapped, and all waste-pipes from sinks, basins, &c., discharging over gullies outside the house. The closets, privies, and receptacles should be in convenient situations, of proper construction, and adapted to the scavenging arrangements of the district. The walls, roof, and floors should be in good repair. Inside walls should not be papered. Every registered room should have special means of ventilation, by chimney if possible, and a window opening freely and directly upon the outer air. There should be kitchen and day-room accommodation apart from the bedrooms. Rooms partially underground should not be registered as sleeping-rooms. There should be a supply of pure water, allowing at least ten gallons per head per day for the maximum number of inmates, and one closet for every twenty registered lodgers. The washing accommodation should, wherever practicable, be in a special place, and not in the bedrooms; the basins for personal washing being fixed, trapped, and fitted with disconnected waste-pipes.

No premises, failing to fulfil the above-indicated requirements, should be approved by the Sanitary Authority for registration as a common lodging-house.

When the lodging-house is without a proper water-supply, and this can be furnished at a reasonable rate, the Sanitary Authority may enforce it (section 81). The keeper is required to lime-wash the walls and ceilings in the first week of April and October in every year (section 82). The Sanitary Authority have power to require the keeper of a house in which vagrants or beggars are received to make returns of persons who have slept there the night before (section 83), and the keeper must always give notice to the Medical Officer of Health and to the relieving officer of any case of infectious disease (section 84). In any urban or rural sanitary district in which Part III. of the Public Health Acts Amendment Act, 1890, has been adopted, any keeper of a common lodging-house who fails to give the notice required by the last-mentioned section is liable to a penalty not exceeding 40*s*., and to a daily penalty not exceeding 5*s*.

Free access must be allowed to officers of the Sanitary Authority to a common lodging-house or any part thereof, and any person who refuses such access will be liable to a penalty not exceeding £5 (section 85).

Section 80 of the Public Health Act, 1875, requires all Sanitary Authorities to make bye-laws (1) for fixing and varying the number of lodgers who may be received into a common lodging-house, and for the separation of the sexes therein; and (2) for promoting cleanliness and ventilation; and (3) for the giving of notices and the taking of precautions in a case of any infectious disease; and (4) generally for the well ordering of such house. The Local Government Board have issued a series of Model Bye-laws for the purposes of this section, of which the following is a summary :—

(*a*) A greater number of lodgers than the maximum from time to time fixed by the Sanitary Authority by a notice served on the keeper of the house must not be accommodated in each room; it is usual to require at least 300 cubic feet of air space per head, but to count two children as one adult. (*b*) In general, no person above ten years of age must occupy the same sleeping-room as persons of the opposite sex, but rooms may be set apart for the sole use of married couples, to the exclusion of other persons over ten years of age, on condition that every bed is screened off. No bed must be occupied by more than one male above ten years of age. (*c*) The yards, &c., must be kept clean and in good order; all floors swept daily, and washed once a week; all windows, painted surfaces, and fittings of wood, stone, or metal kept clean. (*d*) Closets must be kept clean and in good and efficient order. (*e*) Ashpits must be kept clean and in good order; no filth or wet refuse being thrown into ashpits designed for dry refuse only. (*f*) The windows must be opened fully for an hour in the morning and an hour in the afternoon, except in case of bad weather or occupation of the room by a sick person, or other sufficient cause. Beds must be stripped of clothes and fully exposed to the air for an hour each day, and must not be re-occupied within eight hours after being vacated. All refuse and slops must be removed every day before 10 A.M., and all utensils cleansed daily. Every sleeping-room must be provided with sufficient bedsteads, beds, bed-clothes, and utensils for the use of the maximum number of lodgers to be received therein. (*g*) A sufficient supply of suitable basins, water, and towels must be provided for the use of lodgers, and must be kept clean and renewed as required. (*h*) If the keeper finds that any lodger is suffering from an infectious disease, he must at once take all necessary precautions. No person, except a relative or attendant, must occupy the same room as the sick person. If the patient is removed to hospital by the Sanitary Authority, the keeper must afford all facilities for removal, and must adopt all precautions directed by the Medical Officer of Health. He must, if required to do so, temporarily cease to receive lodgers into any infected room. At the end of the case, by removal, recovery, or death, the keeper must at once give notice to the Medical Officer of Health, and must cleanse and disinfect every part of the infected rooms and their contents, and in doing so must comply with all the instructions of the Health Officer. When the cleansing and disinfection are completed, he must give notice thereof to the Medical Officer of Health, and must not receive any lodger into the rooms in question until two days after such notice has been given. (*i*) A copy of the bye-laws in force with respect to common lodging-houses, supplied by the Sanitary Authority, and a statement of the provisions of sections 75 to 89 of the Public Health Act, 1875, must be placed in some conspicuous place in the house, and must not be concealed, altered, obliterated, or injured.

In London.—Outside the City of London the metropolitan common lodging-houses are regulated by the Common Lodging-houses Acts, 1851 and 1853, which, " except as regards the Metropolitan Police District, were repealed by section 343 of the Public Health Act, 1875." Section 3 of the Act of 1851 provided that the Act should be executed within and for all parts of the Metropolitan Police District by the Commissioners of Police. By a provisional order, however, of the Local Government Board, dated May 7, 1894, since confirmed by Parliament, these powers and duties of the Police Commissioners under those Acts have been transferred to the London County Council, from November 1, 1894. Under the Common Lodging-houses Acts of 1851 and 1853, the powers for the control and management of those places are practically the same as those of Sanitary Authorities in other parts of the country under the Public Health Act, 1877; power being given to make regulations for them, subject to confirmation of the Home Secretary (section 9). In the City of London the provisions of the Public Health Act, 1875, as to common lodging-houses appear to apply, the Corporation being the local Sanitary Authority.

In Scotland.—By the Public Health (Scotland) Act, 1897, sections 89 to 100, the provisions respecting common lodging-houses are similar to

those in force in England. The definition, however, of a common lodging-house is peculiar, it being defined as " a house or part thereof where lodgers are housed at an amount not exceeding fourpence per night for each person, whether the same be payable nightly or weekly, or at any period not longer than a fortnight ; and shall include any place where emigrants are lodged, and all boarding-houses for seamen, irrespective of the rate charged for lodging or boarding." The amount charged may, with the approval of the Sanitary Authority, be diminished or raised, but not to exceed sixpence (section 89).

In Ireland.—The Irish Public Health Act of 1878, section 2, defines a common lodging-house to mean " a house in which, or in any part of which, persons are harboured or lodged for hire for a single night, or for less than a week at a time." The provision empowering a Sanitary Authority to remove a lodging-house from the register until a proper water-supply has been provided is compulsory, and not merely permissive as in England (section 92). In the case of failure on the part of the keeper to limewash the walls in the first weeks of April and October in each year, the work can be executed by the Sanitary Authority, and the cost recovered in a summary manner (section 93). Excepting some other minor differences, the provisions of the Irish Act, in respect of common lodging-houses, conform closely with those of the English Act ; while the Model Bye-laws, issued by the Local Government Board for use in England, will also apply, with some small modifications, to Ireland.

TENEMENT HOUSES.

This term is here used to express houses which, while not being common lodging-houses as defined in the last section, are let in lodgings or occupied by members of more than one family. So far as relates to sanitary enactments hereafter to be explained, these tenement-houses, as above defined, are assumed to be only those houses occupied by persons belonging to the poorer classes, and do not embrace houses of higher rateable value.

In England and Wales.—Every Sanitary Authority, in respect of so-called " tenement houses," has power to make bye-laws for their control and management by the Public Health Act, 1875, section 90, and the unrepealed 8th section of the Housing of the Working Classes Act of 1885. These bye-laws should be framed for (1) fixing, and from time to time varying, the number of persons who may occupy a house or part of a house which is let in lodgings or occupied by members of more than one family, and for the separation of the sexes in a house so let or occupied ; (2) for the registration of such houses ; (3) for their inspection ; (4) for enforcing drainage, and the provision of privy accommodation, cleanliness, and ventilation ; (5) for cleansing, limewashing at stated intervals, and for the paving of the yards ; (6) for the giving of notices, and the taking of precautions in case of infectious disease.

Practically, the general tenor of these bye-laws is the same as those proposed for common lodging-houses ; but in the absence of any express limitation, in the sanitary Acts, of their scope, Sanitary Authorities are advised by the Local Government Board to insert a clause in their bye-laws relating to these houses, providing for the exemption of lodging or tenement houses, as to which it may be reasonably inferred that such supervision, as elsewhere a Sanitary Authority alone can sufficiently exercise, will be exercised, in fact, by the lodgers themselves. In other words, it is assumed

that bye-laws are unnecessary in the case of tenement-houses occupied by well-to-do persons.

The Local Government Board have issued Model Bye-laws, dealing with these houses, which are somewhat lengthy. The nature of some of them may be inferred from the models relating to common lodging-houses; but in respect of one or two points, special notice is necessary. Thus, it is suggested that every room should have a notice or placard indicating how many inmates may be received in each sleeping or other department. The minimum free air space allowed, for rooms used exclusively for sleeping, should be 300 cubic feet for every person exceeding ten years of age, and 150 cubic feet for those under ten years. Where a room is not used exclusively for sleeping purposes, these spaces may be increased to 400 and 200 cubic feet respectively.

The Model Bye-laws do not contain provisions for the separation of the sexes. This omission arises from a reasonable doubt whether this is practicable under the ordinary conditions of life in lodgings of the poorer class. Where, however, a Sanitary Authority are satisfied that a rule on this subject can be enforced without hardship, it should be framed and enforced. Another point is that, considering the registration of these houses is not laid down by the law as for common lodging-houses, the landlord should furnish a statement, on requisition by the Sanitary Authority, as to (*a*) the total number of rooms in the house; (*b*) the total number let in lodgings or occupied by members of more than one family; (*c*) the manner of use of each room; (*d*) the number, age, and sex of the occupants of each sleeping-room; (*e*) the name of the lessee of each room; and (*f*) the amount of rent or charge payable by each lessee. The other Model Bye-laws relating to inspection, drainage, privy accommodation, &c., do not materially differ from those proposed for common lodging-houses.

In seaport towns, under section 214 of the Merchant Shipping Act, 1894, the Sanitary Authority may make bye-laws as to *seamen's lodging-houses*, subject to sanction of the President of the Board of Trade. Such bye-laws must, amongst other things, provide for licensing, inspection, general sanitation, publication of the fact of a house being licensed, due execution of bye-laws and regulations, the prevention of persons not duly licensed purporting to keep licensed houses, the exclusion of persons of improper character, and sufficient penalties for breach of such bye-laws, not exceeding £50.

If a Sanitary Authority do not make, revoke, or alter bye-laws in respect of these matters, after notice from the Board of Trade, that body may do so; and an Order in Council may be made requiring all seamen's lodging-houses to be licensed, and none but persons duly licensed shall keep seamen's lodging-houses or let lodgings to seamen in any seaport town or part thereof.

Section 259 of the same Act enables the corporations of municipal boroughs being ports in the United Kingdom to appropriate, with the consent of the Local Government Board, lands belonging to them as sites for sailors' homes.

In London, the regulation of tenement-houses or lodgings other than common lodgings, is within the jurisdiction of the Metropolitan Vestries and District Boards in the administrative county of London, and of the City Corporation in the city, who respectively, by section 94 of the Public Health (London) Act, 1891, are required to make and enforce bye-laws for the several purposes for which Sanitary Authorities may make bye-laws under section 90 of the Public Health Act, 1875. The County Council are the

Local Authority in the administrative county of London for the purposes of the Merchant Shipping Act, 1894, and are under the same obligations to make bye-laws and regulations with reference to seamen's lodgings under that enactment as attaches to Sanitary Authorities in whose districts sea-port towns are situated. In the City of London the same duties devolve on the Corporation.

In Scotland.—As regards lodging-houses other than common lodging-houses, section 72 of the Public Health (Scotland) Act, 1897, says that every Local Authority may, and if required by the Local Government Board shall, make and enforce bye-laws for (1) fixing the number of persons who may occupy a house or part of a house let in lodgings, or occupied by members of more than one family; (2) for the registration of houses so let or occupied; (3) for the inspection of such houses; (4) for enforcing sufficient water-closet accommodation, and for promoting cleanliness and ventilation in such houses; (5) for cleansing and limewashing of the premises at stated times; (6) for the giving notices and the taking of precautions in case of any infectious disease. The provisions of the Merchant Shipping Act, 1894, sections 214 and 259, respecting seamen's lodging-houses, apply to Scotland.

In Ireland.—Section 100 of the Public Health (Ireland) Act, 1878, corresponds to section 90 of the English Act, and empowers Sanitary Authorities to make bye-laws as to houses let in lodgings. Owing to ambiguity of phraseology, it is doubtful whether that section of the Act is in force in the districts in respect of such houses, without a declaration by the Local Government Board. The Housing of the Working Classes Act, 1885, section 8, enabled the Sanitary Authorities in England to make "these bye-laws without any declaration by the Local Government Board, and section 15 of the same Act applied the provisions of section 8 to Ireland." The Act of 1885, with the exception of a few sections which include section 8 but not section 15, was repealed by the Housing of the Working Classes Act of 1890, so that it is very problematical whether section 8 of the 1885 Act is really now in force in Ireland. The provisions for making bye-laws and granting sites for seamen's lodging-houses are the same in the case of Ireland as for England.

ARTISANS' DWELLINGS.

The legislative enactment which enables Sanitary Authorities to deal with this important branch of the Public Health is the Housing of the Working Classes Act, 1890. This Act repealed and consolidated fourteen Acts dealing with the important but large subject of dwellings for the labouring classes. The Act is divided into seven parts; of these, the last four are supplemental to the first three, hence the natural division of the Act is into three parts only. In some details it has been amended or amplified by the Housing of the Working Classes Acts of 1900 and 1903.

Part I. is headed "unhealthy areas," being an amendment and consolidation of the Artisans' and Labourers' Dwellings Acts, formerly known as Cross's Act. The essential point of this part of the Act is to give powers to a Local Authority to clear some well-defined unhealthy area in an urban district, and having removed the offending dwellings, narrow courts, &c., to replace the dwellings so removed by structures in all respects fit for human habitation, and to re-arrange the streets on an improved plan, admitting of plenty of air and light.

Part II. deals with the individual house, or with small groups of houses. The basis of this part is the Act known formerly as Torrens' Act, but the leading idea is practically the same as that characteristic of Part I.; the chief distinction between them being, that while Part I. is applicable only to urban districts and deals with large areas including many houses, Part II. applies to both urban and rural districts and deals with the individual house, or small groups of houses.

Part III. is an embodiment of the Shaftesbury Acts, and is adoptive. It gives to authorities facilities for acquiring or appropriating land for the purposes of erecting thereon buildings suitable for lodging-houses for the working classes. Under this part they can also convert any buildings into lodging-houses for the working classes, and may " alter, repair, enlarge, and improve the same respectively, and fit up and furnish and supply the same with requisite furniture, fittings, and conveniences."

Of the remaining or purely supplemental portions of the Act, Part IV. contains the following important provision. " In any contract made after August 14, 1885, for letting for habitation by persons of the working classes a house or part of a house, there shall be implied a condition that the house is at the commencement of the holding in all respects reasonably fit for human habitation."

The Act thus readily lending itself to division into three main parts, or those dealing with " unhealthy areas," " unhealthy dwellings," and " working-class lodging-houses," it will be more convenient to consider the law relating to the whole question of the housing of the working classes under those three main sections.

UNHEALTHY AREAS.

Part I. of the Housing of the Working Classes Act, 1890, as modified by the corresponding Act of 1903, deals with this subject, and is applicable to England and Wales, the metropolis, Scotland, and Ireland; it enables the various urban Sanitary Authorities, the London County Council, and the Corporation of the City of London to carry out by means of provisional orders, confirmed by Parliament, improvement schemes for the reconstruction and re-arrangement of the streets and houses in unhealthy areas.

To put the Act in motion, it is the duty of the Medical Officer of Health to make " an official representation " in writing to the Sanitary Authority, whenever he sees cause to do so, that within a certain area either any houses or courts are unfit for habitation; or the bad arrangement or condition of the streets or houses, or want of light, ventilation, or proper conveniences, or any other sanitary defects, are dangerous to the health of the inhabitants; and that the evils cannot be effectually remedied otherwise than by re-arrangement and reconstruction of some or all of the streets or houses. Similarly, upon complaint by two justices of the peace, or twelve ratepayers, the Medical Officer of Health must make an inspection and report upon any area alleged to be unhealthy and dangerous to health. If he fails to do so, or reports that it is not an unhealthy area, such ratepayers may appeal to the confirming authority (which in the case of all urban districts is the Local Government Board, and as regards the metropolis is the Home Secretary), who, upon receiving satisfaction as for costs, may then appoint a medical practitioner to inspect the area, and to make representation to them, stating the facts of the case, and whether, in his opinion, the area, or any part thereof, is or is not an unhealthy area. The

representation so made must be transmitted by the confirming authority to the Local Authority, who must treat it in the same manner as if it were an official representation made direct to them in the other or more ordinary way by their own officer (section 16). By section 4 (2) of the 1903 Act, a similar right of appeal against any such complaint is vested in any twelve or more ratepayers of the district.

The Sanitary Authority must consider this or any representation, and if satisfied of the truth thereof, and of the sufficiency of their resources, must declare the area to be an unhealthy area, and frame an improvement scheme. In any case, if the Sanitary Authority refuse or fail to prepare a scheme upon receipt of an official representation, they must report the facts to the confirming authority, who may then order a local inquiry to be held. By section 4 (1) of the 1903 Act, if on report made to them after inquiry the Local Government Board are satisfied that a scheme ought to have been made, they can order it to be done either under Part I. or II. The Order of the Board is enforceable by mandamus.

Having passed a resolution to carry out an improvement scheme, the Sanitary Authority may prepare it, with maps, plans, and elaborate details as to sanitary arrangements, widening the approaches and streets, or otherwise opening out the area. It may exclude any part of the area, or include neighbouring lands; but must provide such dwelling accommodation, if any, for the working classes displaced by the scheme as is required by the Act (section 6). Due publicity must be given to the scheme by publishing advertisements in a local newspaper for three consecutive weeks at any period of the year, naming a place within such area or in the vicinity where a copy of the scheme may be seen at all reasonable hours; and during the month next following the month in which advertisements were published, notices must be served on all the persons interested (section 7, as amended by the 1903 Act). This being done, application must be made by the Sanitary Authority to the confirming authority for a provisional Order. If this authority think fit to proceed with the case, it must direct a local inquiry to be held respecting the correctness of the official representation, and the sufficiency of the scheme. On receiving the report made by this inquiry, the confirming authority may grant a provisional Order declaring the limits of the area to which the scheme relates, and authorising the scheme to be carried into execution. The Order has no validity unless and until it has been confirmed by Act of Parliament, and such Act must be a public general Act (section 8).

In London, accommodation must be provided in or near the area for the whole number displaced, unless the Order decrees otherwise; under certain conditions the Order may accept in substitution equally convenient accommodation not in or near the area, and may dispense with the obligation to any extent not exceeding one-half. Outside the metropolis such provision is only compulsory if (and to the extent) prescribed by the Order (section 11). In assessing the value of property, no additional allowance for compulsory purchase is to be made in regard to any unhealthy portion of the area; and evidence may be given showing that any premises are (1) unfit for habitation, and cannot reasonably be made fit; or (2) in bad repair, or in an insanitary condition; or (3) that the rental is enhanced by reason of overcrowding or use for illegal purposes. In the first case the compensation is to be based upon the value of the land and building materials only; in the second, upon the value after allowing for the cost of necessary repairs; in the third, upon the value apart from such illegal use (section 21).

The Sanitary Authority must, not less than thirteen weeks before taking any fifteen houses or more, give notice to the occupiers by placards, handbills or other notices, and must also, before actually clearing, obtain a certificate from a justice that they have made known their intention of taking the houses in the manner specified in the Act (section 14). The time taken by all these steps is often considerable. It rarely happens that an area is cleared and built upon under four years. If within five years after the removal of any buildings on the land set aside by any scheme authorised by a confirming Act as sites for working-men's dwellings the Sanitary Authority fail to complete it, the Local Government Board have power to sell the land and complete the scheme (section 13).

Reference may conveniently here be made to a practical difficulty which occasionally arises, in connection with this matter of unhealthy areas, in London. Owing to the County Council being the Local Authority outside the city for the purposes of Parts I. and III. of the Housing of the Working Classes Act, 1890, and the Borough Councils the Local Authorities for the purposes of Part II. of the Act, in cases where the area to be dealt with is neither very large nor very small, differences of opinion arise whether it should be dealt with under Part I. or II. of the Act. When Part I. is put in force, the expenses are necessarily borne by the whole of London exclusive of the city. When recourse is had to Part II., the cost primarily falls on the parish or district subject to the Sanitary Authority. To avoid this difficulty, section 72 says that when official representation deals with not more than ten houses, the case is to be dealt with under Part II. It is obvious, however, that this enactment only solves the difficulty in a limited number of cases, hence a further attempt has been made to remove doubts and differences on this matter that may arise between the County Council and the Sanitary Authorities, by leaving the question to be settled in each case by the Home Secretary (section 73).

Another point of importance, in London, is that the official representation by means of which the County Council are to be set in motion must be made either by the Medical Officer of Health of the Council, or by any Medical Officer of Health in London section 5 (1).

Part I. of the Housing of the Working Classes Act, 1890, applying equally to **Scotland** and **Ireland** as to England and the metropolis, no special remarks as to its working in the two former countries are necessary.

UNHEALTHY DWELLING-HOUSES.

The enactments dealing with this matter, for **England and Wales,** are practically the Public Health Act, 1875, sections 91 to 111, and Part II. Housing of the Working Classes Act, 1890. If it can be shown that any house or part of a house is so overcrowded as to be dangerous or injurious to the health of the inmates, no matter whether members of one family or not, and any premises in such a state as to be a nuisance or injurious to health, may be dealt with in any urban or rural sanitary district under the provisions of the Public Health Act, 1875, sections 91 to 111, relating to nuisances, and if so deemed necessary may be closed as unfit for habitation. Where the only object of a Sanitary Authority is to close a house, either for the purpose of checking overcrowding or to induce the owner to make certain necessary improvements in it, it is generally better to proceed under the provisions of the Act of 1875. But where the authorities propose to go further, and to take steps to obtain the demolition of the house, they

must proceed under the Housing of the Working Classes Act, 1890, and the amending Acts of 1900 and 1903.

Part II. of the 1890 Act, which is applicable to all urban and rural Sanitary Authorities in England and Wales, and also, with some minor modifications, to Scotland and Ireland, lays a definite duty upon the Medical Officer of Health to represent to the Local Authority of his district any dwelling-house " which appears to him to be in a state so dangerous or injurious to health as to be unfit for human habitation " (section 30). He may also be moved to inspect and make a representation by complaints in writing from any four or more householders (section 31 (1)); and in the case of an urban district, should the Sanitary Authority let three months pass away after receiving such representation without doing anything, the householders may petition the Local Government Board to hold an inquiry, and the Board, after such inquiry, may make a binding order on the authority (section 31 (2)). It is further the duty of the authority to make, from time to time, inspection of their district to ascertain whether any dwelling-house therein is in a state so dangerous or injurious to health as to be unfit for human habitation; and, if so satisfied that such is the case, either to take measures to close the house by a magistrate's order, under section 97, Public Health Act, 1875, or to give notice to the owner to do certain work, so as to put the premises in proper order, and, on his failing to comply, summon, and at the hearing ask, for the premises to be closed (section 32). The amending Act, 1903, section 8, dispenses with this notice as regards any dwelling-house which, in the opinion of the Sanitary Authority, is either not reasonably capable of being made fit for habitation or in such a state that its occupation should be immediately discontinued. Under section 10 of the 1903 Act, the Sanitary Authority can expedite the gaining possession of a house in respect of which a closing Order has been obtained, by proceeding either under sections 133 to 145 of the County Courts Act, 1888, or under the Small Tenements Recovery Act, 1838, and, moreover, recover from the owner the expenses of these proceedings under the Summary Jurisdiction Acts. When an order for demolition has been made, the owner must comply with it within three months; if he fail to do so, then the local Sanitary Authority may demolish, sell the materials, and, after deducting expenses, pay over the balance to the owner. Moreover, no building likely to be dangerous or injurious to health can be erected on the vacant site or any part of it (section 34). There is power of appeal against any of the Orders under this part of the Act, by any aggrieved person to Quarter Sessions; but notice of appeal must be given within one month after notice of the Order of the Sanitary Authority has been served (section 35).

Section 38 raises the interesting question of what are known as "*obstructive buildings*," or those buildings which, although not in themselves unfit for human habitation, are so situated that by reason of their proximity to or contact with any other buildings they stop ventilation, or make other buildings insanitary, or prevent proper measures from being carried into effect for remedying nuisances. In any of the above cases, it is the duty of the Medical Officer of Health to make " a representation " of the particulars to his Sanitary Authority, stating that in his opinion it is expedient that they should be pulled down. A similar representation may be made by any four or more inhabitant householders. In either case, the Sanitary Authority must make inquiries as to the facts, and as to the cost of acquiring the land and pulling down the building. If they decide to proceed, the authority can make an order for the demolition of the building, after giving the owner notice and an opportunity of stating his objections, and subject

to appeal to Quarter Sessions. When such an Order has been made, and there is no appeal, or the appeal fails or is abandoned, the Sanitary Authority may compulsorily purchase the site within a year from the date of the Order, or if it were appealed against, from the date of its confirmation, unless the owner pulls down the obstructive building; in such case he is compensated for the building only. In case of difference as to price, the matter goes to arbitration. The owner cannot subsequently re-erect an obstructive building on the vacant site, nor one that is dangerous or injurious to health. Where the authority purchase land compulsorily under the above powers, a part only of the building can be taken if, in the opinion of the arbitrator, no material detriment will be suffered; but in assessing compensation, the value of the part and also the severance of the part are both taken into consideration. As probably the value of the buildings, which previously had been injuriously affected by the obstructive buildings, will be increased by the removal of the latter, the principle of "betterment" is adopted, and a Local Authority may apportion the compensation on such buildings, declaring them to be private improvement expenses, and levy improvement rates (section 38 (8)).

Where the lands are purchased by the Sanitary Authority, they may keep the site wholly or partly as an open space, highway, or other public place, or, with the consent of the Local Government Board, sell such portion of the site as is not required.

Section 39 empowers the Sanitary Authority to prepare a scheme for utilising as a highway or open space, or appropriating or exchanging for the erection of working-class dwellings, the site of any building ordered to be demolished under this part of the Act, if it appear to them that it would benefit the health of the inhabitants of the adjoining houses; they may also prepare an improvement scheme for any unhealthy area too small to be dealt with under Part I. of the Act. Notice of the scheme must be given to the owners just as in Part I.; after this a petition must be presented to the Local Government Board for an Order confirming the scheme. It must be noted that in this case under Part II., the petition *in every case* must be to the Local Government Board, while under Part I., so far as London is concerned, it is to be addressed to the Home Secretary. The Local Government Board may, if they think fit, hold a local inquiry, and, if satisfied, may by Order sanction the scheme with conditions or modifications. In these Orders the Local Government Board must require the insertion of provisions, if any, for the dwelling accommodation of persons of the working classes who may be displaced as seem to them to be necessary under the circumstances. On the Order being made, the Sanitary Authority must endeavour to come to terms with the owners as to price, and, if an agreement is arrived at, the Order takes effect without confirmation. If they do not agree, the authority must insert a notice of the Order in the *London Gazette*, and also serve notices thereof on the owners of every part of the area; but the notice is not restricted to particular months. If two months pass, and no owner petitions against it, or if he petitions and then withdraws it, the Board confirm the Order; but if opposed, the Order is only provisional, and has to be confirmed by Parliament. This procedure is somewhat less complicated than that under Part I., and in the case of small areas fairly expeditious; but when the Order is opposed, the delay and expenses incidental to carrying the scheme through are often large, and frequently act as a check upon action being taken by Local Authorities in respect of the matters which it is the aim of this part of the Housing of the Working Classes Act, 1890, to remedy.

When an official representation has been made under Part II., or a closing Order obtained, all Rural Authorities, the Metropolitan Borough Councils, but not urban Sanitary Authorities, save those named, must forward to their County Council a copy of such "representation, complaint, information, or closing Order," and also report from time to time all further proceedings. If it appear to the County Council that a closing Order should be applied for, or an Order for demolition made, or steps taken for pulling down an obstructive building, and if the Local Authority, after due notice from the County Council, fail to adopt such measures, the Council may by resolution take over and exercise the powers of the Local Authority in respect of such buildings, recovering the expenses from the Local Authority (section 45).

Every Sanitary Authority must annually furnish the Local Government Board with an account of what has been done, and of all moneys received and paid by them during the previous year, in carrying into effect the purposes of this part of the Act (section 44). Except in boroughs, a representation by the county Medical Officer of Health, if forwarded by the County Council to any Sanitary Authority, has, for the purposes of Part II. of Housing of the Working Classes Act, 1890, the same effect as if made by the Medical Officer of Health of the district (section 52).

In the County of London, this part of the Act is primarily entrusted to the Borough Councils; but the County Council may prepare schemes under Part II. if they think fit, and may apply to the Home Serecetary to order a contribution from the district authority, who, in like manner, if they proceed, may apply for a contribution from the County Council (section 46).

In Scotland, section 45, or that provision by which the powers of a district authority which refuses to proceed can be taken over by a County Council, does not apply; with this exception the enactments under Part II. of the Housing of the Working Classes Act, 1890, are the same as in England. The provisions of Part II. are likewise the same for **Ireland** as for England, with the exception that sections 45 and 52 do not apply in Ireland. Where notices are published in the *London Gazette* for England, the same in Ireland must appear in the *Dublin Gazette*.

LODGING-HOUSES FOR THE WORKING CLASSES.

This expression includes separate houses or cottages for the working classes, whether containing one or several tenements. The provision of these houses by a Sanitary Authority depends upon the powers conferred by Part III. of the Housing of the Working Classes Act, 1890, and the amending Acts of 1900 and 1903. A peculiarity about this part of the Act is that it is "adoptive," and cannot be in force in any district until it has been adopted by the Sanitary Authority. In rural districts it can only be adopted after a local inquiry by the County Council, and a certificate that "accommodation for the housing of the poor is necessary, and that there is no probability that such accommodation will be provided without the execution of this part of the Act, and that, having regard to the liability which would be incurred by the rates, it is, under the circumstances, prudent for the authority to undertake the provision of such accommodation." In urban districts, the adoption of the Act is subject to the sanction of the Local Government Board. In the City of London, the administration of this and other parts of the Housing of the Working Classes Act, 1890, is vested

in the Corporation. Outside the city, in the metropolis, the administration of Part III. is vested in the County Council.

Having adopted Part III. of the Act, the Sanitary Authority is empowered to purchase or rent land, or to appropriate any lands for the time being vested in them or at their disposal, and on such land to erect any buildings suitable for lodgings for the working classes, and to convert any buildings into lodging-houses for those classes. They may also contract for the purchase or lease of any lodging-houses for the working classes already or hereafter to be provided, and also sell any land vested in them for these purposes, and apply the proceeds in or towards the purchase of other more suitable lands (sections 53 to 60). By the Act of 1900, an urban authority can acquire or establish these lodging-houses outside their district.

The management of lodging-houses thus established or acquired is vested in the Local Authority, who may make reasonable charges for the tenancy or occupation (section 61). The authority may also make bye-laws for their management and use, it being obligatory, except in the case of lodging-houses occupied as separate dwellings, to make provision in the bye-laws for the following purposes:—" (1) For securing that the lodging-houses shall be under the management and control of the officers, servants, or others appointed or employed in that behalf by the authority. (2) For securing the due separation at night of men and boys above eight years old from women and girls. (3) For preventing damage, disturbance, or interruption, and indecent or offensive language and behaviour and nuisances. (4) For determining the duties of the officers, servants, and others appointed by the authority" (section 62).

These lodging-houses are distinctly for the working classes, and not to be used by persons in receipt of parochial relief. This relief, save for accident or temporary illness, disqualifies a tenant (section 63). Lodging-houses, thus established, are to be at all times open to inspection by the officers of the Sanitary Authority of the district (section 70).

The expenses of urban Sanitary Authorities in supplying these lodging-houses will be borne out of the rates. Under the Housing of the Working Classes Act, 1903, the maximum period for the repayment of loans for the purposes of these Acts is raised to eighty years. The principle of the Local Government Board in respect of these repayments is eighty years for re-payment of loans for purchase of freehold land and sixty years for loans for the erection of buildings. Those of rural Sanitary Authorities are to be defrayed as special expenses on the contributory places in respect of which they are incurred; or, in special cases, they may be defrayed as general expenses in the execution of the Public Health Acts, and if they are not to be borne by the whole of the district, they will be paid out of a common fund to be raised in the manner provided by the Public Health Act, 1875, section 229. If after seven years' trial a Sanitary Authority find these lodging-houses too expensive, they may sell them, in the case of urban authorities, with the consent of the Local Government Board, and in the case of rural authorities with the consent of the County Council.

The application of this Part III. of the Act to **Scotland**, if adopted, involves one small distinction from its similar application in England. It is that the consent of the Local Government Board is necessary in the case of *both* rural and urban districts before these lodging-houses can be provided.

In Ireland, the application and operation of Part III. of the Housing of the Working Classes Act as regards urban Sanitary Authorities is

practically identical with its adoption in England. There is this difference, however, that the consent of the Treasury, instead of the consent of the Local Government Board, is required to the appropriation of any lodging-house purchased or taken on lease, and to the sale and exchange of lands. The Commissioners of Public Works, acting with the consent of the Treasury, may advance money for the purposes of the Act, and favourable terms have been laid down by the Treasury. The operation of Part III. of the Act, in rural districts, is practically limited to municipal towns. Its general adoption by purely rural authorities is rendered unnecessary owing to the special facilities afforded by the various Labourers (Ireland) Acts of 1883, 1885, 1886, 1891, and 1892, for the erection of houses for agricultural labourers by any rural Sanitary Authority.

These Acts define an agricultural labourer to mean "a man or woman who does agricultural work for hire at any season of the year on land of some other person or persons, and includes hand-loom weavers and fishermen doing agricultural work as aforesaid, and also herdsmen." The general scope of these Acts amounts to this; that any twelve persons, whether rated for the relief of the poor or not, provided that if not so rated they are agricultural labourers within the meaning of the Acts, and are employed in the district at the date of the representation, may represent to a rural Sanitary Authority that, in the portion of the district in which they reside, the existing house accommodation for agricultural labourers and their families is either deficient or unfit for human habitation. If the Sanitary Authority are satisfied of the truth of the representation, and of the sufficiency of its resources, they are to make an "improvement scheme" for the erection of dwellings, with garden allotments thereto not exceeding one statute acre. The subsequent procedure for obtaining sanction to the scheme is very similar to that of the English Act of 1890. Parliamentary confirmation of provisional Orders is unnecessary; they become absolute if no petition is lodged against it within one month after the making and publication of the Order by an owner or occupier of land proposed to be taken compulsorily, or by twelve ratepayers in any area of charge declared by the Order to be chargeable with the expenses of the scheme. If a petition be lodged, the objections to the Order are adjudicated upon by the Lord Lieutenant in Council, who has power to confirm, modify, or to disallow any provisional Order.

CELLAR DWELLINGS.

The Public Health Act, 1875, section 71, prohibits, for **England and Wales,** the separate occupation as a dwelling of any cellar (including any vault or underground room) built or rebuilt after the passing of the Act, or which was not lawfully so let or occupied at the time of the passing of the Act. Any one passing the night in a cellar is deemed to occupy it (section 74). No cellar could be considered to be lawfully let or occupied at the time of passing the 1875 Act which was not so let or occupied previously to August 7, 1866; and in the case of some few urban sanitary districts, where section 67 of the Public Health Act of 1848 was still in force in 1875, no cellar could be lawfully let or occupied as a dwelling which was not so let or occupied prior to August 31, 1848.

Cellar dwellings, the letting or occupation of which are not forbidden under section 71, are prohibited by section 72 from being let or occupied unless they comply with the following requirements :—(*a*) The height must

in every part be at least 7 feet, 3 feet of which must be above the level of the adjoining street. (*b*) An open area at least 2½ feet wide in every part, and 6 inches below the level of the floor, must extend along the whole frontage. It may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 foot below the floor. (*d*) There must be proper closet and ashpit accommodation. (*e*) There must be a fireplace and chimney, and (*f*) a window at least 9 square feet in area, made to open. The window of a back cellar let or occupied along with a front cellar need only be 4 square feet in area.

Any person who lets, occupies, or knowingly suffers to be occupied for hire or rent any cellar contrary to the Act is liable for every offence to a penalty not exceeding 20*s*. for every day of default (section 73). Where two convictions relating to the occupation of a cellar as a separate dwelling have taken place within three months, a Court of Summary Jurisdiction may close, either temporarily or permanently, the premises, as it deems to be necessary (section 75).

In London.—The provisions as to cellar dwellings by sections 96 to 98 of the Public Health (London) Act, 1891, differ somewhat from those given in the preceding section. A cellar dwelling or underground room must not be occupied in London unless :—(*a*) Every part is 7 feet high, and the ceiling is at least 3 feet above the surface of the adjoining street; but if the area outside is as much as 6 feet in width, or not less wide than the depth of the floor below the ground level, then the height may be 1 foot above the street. (*b*) Every wall has a damp-course, and, if in contact with the soil, is effectually secured from damp from the soil. (*c*) There is an open area outside along the frontage, 4 feet wide in every part, and 6 inches below the floor level. It may be crossed by steps, but not opposite a window. (*d*) The area and the soil immediately below the room are effectually drained. (*e*) The hollow space (if any) below the floor is ventilated to the outer air. (*f*) Any drain passing under the room is properly constructed of gas-tight pipe. (*g*) The room is effectually secured against the rising of any effluvia or exhalation. (*h*) There is a proper water-closet and ashpit in a convenient place. (*i*) There is effectual ventilation. (*j*) There is a fireplace, with chimney. (*k*) There are one or more windows opening directly into the open air; the window-area being at least one-tenth of the floor area, and so constructed that at least half of each window can be opened, and in each case opening to the top.

The same conditions apply to underground rooms occupied separately as dwellings before January 1, 1892; but the Sanitary Authority, either by general regulations or upon special application by the owner, may modify any conditions newly imposed by this Act which involve structural alteration of the building. The power as to closure of underground rooms after two convictions is the same as under the 1875 Act.

In Scotland.—Under the Public Health (Scotland) Act, 1897, sections 74 to 76, the occupation of cellars or underground rooms is regulated under similar conditions to those in force in England and Wales.

In Ireland.—Practically there are no differences between the provisions of the Irish and English Public Health Acts under this heading, section 82 of the former corresponding to section 71 of the latter.

CANAL BOATS.

Under the Canal Boats Acts, 1877 and 1884, the term canal includes any river, lake, water, or inland navigation being within the body of a country, whether it is, or is not, within the ebb or flow of the tide. A canal boat includes any and every vessel, however propelled, used for conveyance of goods along a canal, as above defined, but does not include a ship registered under the Merchant Shipping Act, 1894, unless the Local Government Board orders otherwise, which it may do on the representation of a Sanitary Authority or any of its inspectors. The legislation which controls the sanitation of the large floating population on the canals is the Canal Boats Acts of 1877 and 1884. These Acts are only applicable to England and Wales. In the following remarks, when the number of a section is quoted, unless expressly stated to be otherwise, such numbering refers to the Act of 1884.

By these Acts the supervision of the canal boats is placed under every Sanitary Authority through whose district a canal takes its course, or which has a piece of water coming under the definition of the word canal (*see* page 22). It is further the duty of these authorities to report, within twenty-one days after December 31 in every year, as to the execution of the Acts, and as to the steps taken by the Authority during the year to give effect to them (sections 3 to 5).

No canal boat must be occupied as a dwelling unless it is registered under these Acts, and then only by the number of persons of the age and sex for which it is registered (section 1). The owner can register the boat with any registration authority having a district abutting on the canal on which such boat is accustomed or intended to ply; and the boat must be registered as belonging to some place which is within the said district (section 7). When the boat passes from the canal on which the district of the authority with whom it has been registered abuts, its original registry will be recognised as operative on other canals whereon it may ply. If a canal boat is used in contravention of the Acts, the master of the boat, and also the owner, if he is in fault, will be each liable to a fine not exceeding 20*s.* for each occasion on which the boat is so used. Directly a canal boat ceases to be inhabited, it is no longer subject to the Canal Boats Acts. Upon registration, two certificates must be given to the owner, identifying the owner and the boat, and stating the place to which it belongs, and the number, age, and sex of the persons allowed to dwell in the boat. The master of the boat must carry one of these certificates (section 3). A boat cannot be considered to be registered unless it is marked with (*a*) the name of the place to which the boat belongs; (*b*) the number; (*c*) the word "registered," thus, "No. 129, Hanley, Registered." Further, a boat will not be deemed to be lettered, marked, and numbered in conformity with these requirements unless it is so lettered, marked, and numbered on both sides, or in some suitable position plainly visible from both sides of the boat (section 7). A certificate of registration will cease to be in force in the event of any structural alterations having been made in the canal boat affecting the conditions upon which it was originally registered (section 1).

If any person on a canal boat is suffering from an infectious disease, the Sanitary Authority of the place where the boat is shall adopt such precautions as appear necessary, upon the certificate of the Medical Officer of Health, or other legally qualified practitioner; and may remove such sick person, and exercise the other powers conferred by the Public Health Act,

1875, in this respect, and may detain the boat as long as is necessary for cleansing and disinfecting (section 4, Act of 1877). If any person duly authorised by the Sanitary Authority has reason to suspect any contravention of the Act, or that a person on board is suffering from an infectious disease, he may enter the boat for the purpose of inspection between 6 A.M. and 9 P.M., and may require the master or whoever is in charge of the boat to afford him facilities for so doing, and to produce the certificate of registry of the boat (section 5, Act of 1877).

Section 2 of the Act of 1877 directs the Local Government Board to make regulations :—(i) for the registration of canal boats ; (ii) for lettering, marking, and numbering such boats ; (iii) for fixing the number, age, and sex of persons who may be allowed to dwell in a canal boat, having regard to the cubic space, ventilation, separation of the sexes, general healthiness, and convenience of accommodation ; (iv) for promoting cleanliness and habitable condition of such boats ; and (v) for preventing the spread of infectious disease by canal boats.

In pursuance of the above powers, the Board issued an Order in 1878, prescribing a series of regulations which are still in force. The following is a summary of their principal sanitary provisions :—

There must be at least one dry, clean, and weather-proof cabin in good repair. An after-cabin, intended to be used as a dwelling, must contain not less than 180 cubic feet of free air space, and a fore-cabin 80 cubic feet ; every such cabin must have means of ventilation besides the door, and must be so constructed as to provide adequate sleeping accommodation. One cabin must contain a stove and chimney. The boat must be furnished with suitable storage for three gallons of water. If intended to be ordinarily used for foul cargoes, the hold must be separated from any inhabited cabin by a double bulk-head with an interspace of 4 inches, and the bulkhead next the cargo must be water-tight. Not less than 60 cubic feet of air space must be allowed for each person over twelve years of age, and not less than 40 cubic feet for each person under that age. In " fly-boats " worked by shifts, a cabin occupied at the same time by two persons must have a capacity of 180 cubic feet. A cabin in which a married couple sleep must not be occupied at the same time by any other male above fourteen, or female above twelve years of age. Males above fourteen and females above twelve years of age must not occupy the same sleeping-cabin at the same time, but reservation is made for married couples, and also (under certain conditions) in respect of boats constructed prior to 1878. The interior of the cabin must be repainted every three years, and must be kept clean Bilge water must be pumped out daily. The master of the boat must at once notify the occurrence of any case of infectious disease on the boat to the Sanitary Authority of the district through which the boat may be passing, and also to the Sanitary Authority of the place of destination ; he must also inform the owner, who is required to notify to the Sanitary Authority of the place to which the boat belongs. If the boat is detained by the authority for purposes of disinfection, the Sanitary Authority must obtain a medical certificate that the boat has been cleansed and disinfected, and shall cause such certificate to be delivered to the master of the boat, who cannot proceed until that certificate has been obtained. The Sanitary Authority may pay a reasonable remuneration for any such certificate.

The Acts contain special provisions with respect to the education of children living in canal boats, and enable the Education Department to make regulations on this subject (sections 6 and 12, Act of 1877). Section 4 of the Act of 1884 requires the Local Government Board to make inquiries, from time to time, by an inspector or inspectors, specially appointed for the purpose, as to the working of these Acts and Regulations, and to report annually thereon to Parliament.

So far as their parishes and districts are not within the jurisdiction of the Port Sanitary Authority for the Port of London, the Borough Councils are the Local Authorities for the purposes of the Canal Boats Acts, 1877 and 1884, in the metropolis.

MOVABLE DWELLINGS OTHER THAN CANAL BOATS.

There is a considerable population who occupy movable dwellings other than canal boats, such as vans, tents, sheds, and other similar structures, and whose conditions of life are often a menace to the Public Health. These individuals are for the most part of the so-called gipsy class, while at certain seasons of the year their numbers are materially increased by others engaged in hop- or fruit-picking. In order to control the sanitation of this more or less vagrant population, Sanitary Authorities possess certain powers under the Public Health Act, 1875, under the unrepealed 9th and 10th sections of the Housing of the Working Classes Act, 1885, and under the Public Health (Fruit-Pickers' Lodgings) Act of 1882.

Section 9 of the Housing of the Working Classes Act, 1885, provides that a tent, van, shed, or similar structure, used for human habitation (exclusive of those used by a portion of His Majesty's military or naval forces), which is in such a state as to be a nuisance or injurious to health, or which is so overcrowded as to be injurious to the health of the inmates, whether or not members of the same family, shall be deemed to be a nuisance within the meaning of section 91 of the Public Health Act, 1875, and the provisions of that Act shall apply accordingly. By section 10, any Sanitary Authority may make bye-laws in regard to such habitations. Power of entry between 6 A.M. and 9 P.M. is given to any person duly authorised by the Sanitary Authority or by a Justice of the Peace, if such person has reasonable cause to suspect any contravention of the Act, or of any bye-laws made under it, or that there is in such habitation any person suffering from any dangerous infectious disease. If any such person is obstructed in the performance of his duty under the above provisions, the person obstructing him will be liable on summary conviction to a fine not exceeding 40*s*.

As regards the accommodation and lodging of hop- and fruit-pickers, every Sanitary Authority has power under section 314 of the Public Health Act, 1875, to make bye-laws for securing the decent lodging and accommodation of persons engaged in hop-picking within the district of such authority. This power has been extended by the Fruit-Pickers' Act of 1882, so as to enable the same authorities to make bye-laws for securing decent and proper accommodation and lodging of those engaged in the picking of fruit and vegetables.

For the proper control and regulation of the tents, sheds, barns, or other places occupied as temporary dwellings by hop-pickers and others, but not of places inhabited throughout the year, the Local Government Board have suggested Model Bye-laws. Of these, the following is a brief summary :—

(*a*) The habitations must be clean, dry, weather-proof, ventilated, and lighted. (*b*) At least 16 square feet of floor space must be allowed in them for each adult and for every two children under ten years of age. (*c*) When intended for the reception of adults of different sexes, the habitations must be so furnished or provided that every bed is properly separated from any adjoining bed by a suitable screen or partition to secure adequate privacy to the occupants. (*d*) There must be a separate cooking-place for every fifteen persons authorised to be received. (*e*) There must be a sufficient supply of good water for drinking, cooking, and washing. (*f*) There must be adequate privy accommodation for the separate use of each sex. (*g*) Every lodger or occupant shall be provided with a sufficient supply of clean dry straw, or other clean, dry, and suitable bedding, which must be changed or properly cleansed from time to time, as occasion may require. (*h*) Every part of the interior of the premises, the cook-houses, and privies must be thoroughly cleansed immediately before any person is received to lodge therein, the internal surfaces limewashed, and all offensive accumulations cleared away ; this cleansing and limewashing must be done at least annually and repeated as required from time to time during the period of occupation.

In the Metropolis, the various Sanitary Authorities have similar powers and duties to those of other authorities in England and Wales in relation to tents, vans, sheds, or other similar structures used for human habitations, but their action in this matter will be taken by applying section 95 of the Public Health (London) Act of 1891, read in conjunction with section 9, Housing of the Working Classes Act, 1885.

As regards **Scotland** and **Ireland,** these provisions of the Working Classes Act are of very doubtful application ; while those of English Statutes dealing with hop- and fruit-pickers' lodgings do not apply.

LAW RELATING TO INFECTIOUS DISEASE HOSPITALS.

In England and Wales, the Public Health Act, 1875, by sections 131 to 133, enacts that any Sanitary Authority may build or contract for the use of hospitals for their district, two or more authorities, if necessary, combining for this purpose. The Sanitary Authority may recover from a patient, who is not a pauper, the cost of his maintenance in such hospital ; and may, with the sanction of the Local Government Board, themselves provide or contract for a temporary supply of medicine and medical assistance for the poor of their district. And the Infectious Disease (Prevention) Act, 1890, and the Infectious Diseases (Notification) Act, 1899, requires the same authorities to provide free temporary shelter with any necessary attendance for the members of any family in which infectious disease has appeared, who have to leave their dwellings to allow of disinfection by the Sanitary Authority. Any person suffering from any infectious disease, and being an inmate of a hospital for infectious diseases, who, upon leaving, would be without accommodation in which due precautions could be taken against the spread of infection, may, by order of a justice, be detained in hospital at the cost of the Sanitary Authority for any specified period, and such period may be extended as often as necessary (section 12, Act of 1890).

With a view to promote the establishment of infectious hospitals, a very important Act was passed in 1893, called the Isolation Hospitals Act, giving to County Councils limited power to secure the provision of isolation hospitals in their county. It applies to England and Wales generally, but not to London or to any county borough ; other boroughs are also exempt, except by Order of the Local Government Board, if the population be less than 10,000 at the last census, or by consent of the Corporation if the population be 10,000 or more. A *hospital district* under this Act may consists of one or more local areas ; a " local area " being defined as including an urban or rural sanitary district, or any contributory place. This district is constituted by Order of the County Council. To put this Act into force, the County Council may take the initiative by directing their Medical Officer of Health to report as to the hospital requirements of any part of their county, and act upon his report ; but they may also be set in motion by a petition from any Local Authority, or from twenty-five ratepayers in any contributory place. The next step is for the County Council to hold a local inquiry, after which they make an Order constituting the hospital district and defining its extent. No local area can be included in a hospital district without the consent of its Local Authority, if it already has (in the judgment of the County Council) adequate accommodation ; nor must a hospital district be formed for one local area only, or for one or more local areas within the same rural sanitary district, without the consent of the

Sanitary Authority, unless the County Council are satisfied that the Sanitary Authority are unable or unwilling to make suitable provision for the purpose. The Order constitutes a hospital committee, consisting of local representatives, but if a grant be made out of county funds the committee may consist wholly or in part of County Councillors. The Order further gives the committee power to provide and maintain a hospital; and apart from this they are authorised by the Act to make temporary arrangements for isolation, and to establish district hospitals in cottages or small buildings. They may also (subject to any regulations made by the County Council) undertake the training of nurses, and may charge for their attendance outside the hospital. Every hospital is to be provided with one or more ambulances, and must, if practicable, be "in connection with the system of telegraphs" (section 13).

The County Council have the power of inspecting any such hospital and of raising money by loan for the purposes of the hospital.

"Structural" and "establishment expenses" are borne by the several local rates of the constituent local areas, in proportions to be fixed by the County Council's Order. The cost of conveying, removing, feeding, medicines, disinfecting, and "all other things required for patients individually, exclusive of structural and establishment expenses," are termed "patients' expenses." For ordinary non-pauper patients they are to be paid by the Local Authority out of the rates of the local area from which the patient came, but the guardians are responsible if poor-law relief had been given at or within fourteen days of the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, on such terms as the committee may appoint ("special patients' expenses") (sections 17 to 19).

The Isolation Hospital Act, 1901, provides that a Sanitary Authority having possession of a hospital for the reception of sick may, with the sanction of the Local Government Board, transfer it to the County Council for appropriation to a district under the Act of 1893 as an infectious disease hospital, and the County Council may contribute to the expenses of such a hospital.

In Scotland, by section 66 of the Public Health Act, 1897, any Local Authority may, singly or in combination with other authorities, and if required by the Local Government Board shall provide and maintain, for use of inhabitants of their district, infectious disease hospitals, temporary or permanent.

In Ireland the general provisions for the erection and maintenance of infectious hospitals as contained in the Public Health (Ireland) Act, 1878, are, with the exception of some minor points, similar to those of the English Act of 1875.

CHAPTER XI

SCAVENGING AND CLEANSING

UNDER this heading we have (1) the collection and removal of town and house refuse from premises, and (2) the cleansing of earth-closets, privies, middens and cesspools. In each case there follows naturally the question of the ultimate disposal of the material.

Town and House Refuse.—The effective disposal of civic waste, consisting of dry refuse, paper, rags, and other more or less combustible material, constitutes one of the greatest difficulties which every Sanitary Authority has to face. The difficulty is increased further by the fact that the material to be dealt with varies in quality and quantity according to the season, the kind of fuel used, and the habits of the people. The magnitude of this problem of refuse disposal is apparent when we realise that, for urban areas, the quantity of ashbin refuse averages from 140 to 250 tons annually for each 1000 inhabitants. Much of this might be obviated if individual householders would burn in their own grates such materials as paper, rags, potato peelings, cabbage leaves, and similar substances. Few, however, do so, with the result that the average dustbin contains an objectionable amount of readily decomposable material, which, unless rapidly and effectively removed, conduces soon to become an actual and serious menace to health.

Two forms of receptacle are used for house refuse, an ashpit or a dustbin. An *ashpit* is a fixed receptacle for the reception of house refuse; it should be small, so as not to hold more than a week's refuse. No part should be below ground level. The floor and walls should be lined with a smooth impervious cement, and the ashpit should have a hinged cover to keep out the rain, and a door at one side to facilitate emptying. The ashpit should be at least 6 feet distant from any wall of a house. Fixed receptacles of this kind should be discouraged. A *dustbin* is a portable ashpit and made usually of galvanised iron with a tight-fitting lid. This design can be kept clean and facilitates direct transference of the waste material to the collecting cart. This vehicle should invariably be provided with a cover. The actual removal of house and town refuse from premises and streets constitutes an important part of municipal work. In most towns, house refuse is removed weekly, sometimes less frequently, while in some places removal twice or three times a week is secured. A daily removal is the right and proper system, as decomposition and the dangers associated with it have then no chance of becoming serious.

The disposal of this refuse constitutes a problem of increasing difficulty, and the method adopted varies according to local circumstances. In some places, this dustbin refuse is used for the filling-in of pits and excavations, or for raising the level of low-lying land preparatory to utilisation as building sites; this is a most pernicious practice and should be opposed in every way. An alternative procedure is to sift and sort the refuse at a depôt. The cinders and coke, along with the fine ashes, are sold to brick-makers as

"breeze"; the clinkers, broken crockery, &c., or "hard core," is used for road-making; and the "soft core," consisting of vegetable and animal refuse, is sold for manure. The remaining substances, such as scraps of iron, tin, paper, bottles, rags and corks are separated out and sold. This procedure is not commendable, mainly owing to its disgusting nature and liability to affect unfavourably the health of those engaged in sorting and sifting. In some places, where a river or tide-way is conveniently placed, house and town refuse is placed in barges and taken out to sea and there deposited. This method is obviously limited in its applicability. A fourth and more usual method is to burn all house and street refuse in special furnaces or destructors, which destroy all combustible substances, leaving as a residuum a mass of hard material, called clinkers, which may be utilised subsequently for road-making or ground down and mixed with lime to form cement. In certain places, the steam generated from boilers connected with these furnaces is utilised for electric lighting, traction, water or sewage pumping,

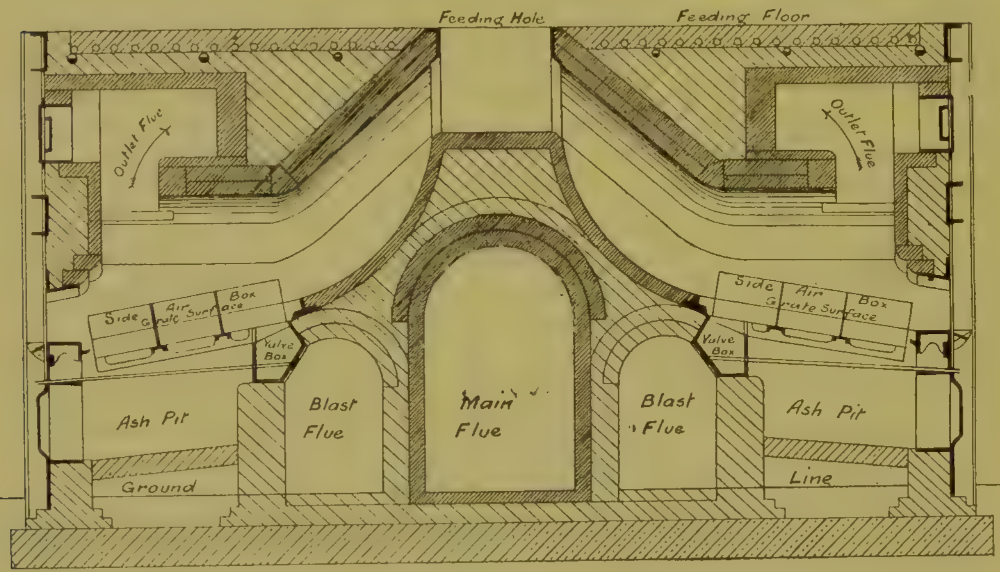


FIG. 65.—SECTION OF A BACK-TO-BACK HORSFALL REFUSE DESTRUCTOR.

and other forms of useful work. Hitherto, the evaporation of one pound of water per pound of refuse burnt has been considered a good result, but with modern furnaces an average evaporation of 1·43 lb. of water can be obtained.

The object of every destructor is to convert the refuse into fixed and harmless products by means of combustion, and the transformation of organic matter into innocuous forms of vapour, carbon dioxide and nitrogen. Many types of destructor have been designed and consist of furnaces of a varying number of cells capable of being charged in different ways. The furnaces are commonly fitted with multitubular or other boilers, and the necessary draught obtained naturally or by means of fans or steam blowers. They may be divided into two chief groups, the single-cell system, such as those of Horsfall, Fryer, Baker, and Warner; and the double-cell or continuous grate system, as in Meldrum's, Heenan's, and Sterling's. Each cell has a sloping hearth and firegrate, with top opening at the back for the admission of refuse. Furnace frames and doors are provided for the removal of clinkers; beneath the bars is situated an ashpit, which is practically a reservoir into which the dust and fine ash fall. The top of the destructor forms a level platform upon which the refuse is tipped from carts, and each furnace has a feeding hopper, which discharges by means of a lever worked

from above. The employment of forced draught has resulted in the production of high-temperature furnaces, in which the principles of construction are very similar to those of the Fryer type. In the best modern forced draught, high-temperature destructors, the gases enter the boiler chamber at a temperature of 2000° F., and in a well-managed plant the temperature can be maintained at 1600° F. The Horsfall back-to-back type is fitted with forced draught, provided by two patent steam blowers placed at the end of the blast flues. By the use of these blowers the temperature in the ashpit is increased to 400° F., the blast being turned off when trimming the fires. In connection with the best of these installations, centrifugal dust-catchers have been placed at the foot of the chimney or vertical shaft, and also solder-extraction furnaces, designed to recover tin and solder from old cans. In the Meldrum destructor, the furnace has one continuous grate with four sets of firing-doors, the products of combustion having to pass over the whole range of fires. The ashpit is divided into four closed compartments, each firing-door having its own separate ashpit, in each of which are fixed two blowers which draw their air through the generator. The fires are clinkered from each door in rotation, three fires being kept always charged, and the temperature of the furnaces maintained at incandescence. The gases pass from the combustion chamber through a Lancashire boiler placed in the main flue. The Heenan destructor is similar in many respects to the Meldrum type, the cells being arranged in series, and the gases from each grate deflected to each adjacent grate in turn by an undulating arch.

The average cost of burning refuse in these modern forced draught destructors works out at about 1*s.* 8*d.* in the metropolitan area and 1*s.* a ton in the provinces; but the efficient and economic working of these furnaces depends largely upon supervision and the maintenance of high temperatures, which can be obtained only by continuous feeding. In addition to the regular and proper feeding of the cells, it is necessary for the prevention of nuisance that the fires be stoked regularly and systematically, and that the blast be cut off each time during the clinking process. Given a good destructor and proper management, civic waste and house refuse are reduced to about one-third their original bulk, the residue being innocuous clinker, metallic refuse and dust.

Removal of Excreta by Dry Methods.

The use of sewers and methods of removing excreta by water are in many cases impracticable. Either a fall cannot be obtained; or there is insufficient water; or the severity of the climate freezes the water for months in the year, that removal by its means cannot be attempted. Under these circumstances either the excreta will accumulate about houses, or must be removed in substance daily or periodically.

Middens.—In places where no facilities exist for the use of water-closets, recourse has to be had to some dry method of removing excreta from the house. This, in many cases, necessitates such arrangements as middens or privies and pail closets, in which are used ashes, earth, &c. Until recent times, *open* middens or pits were the almost universal receptacle for the excretal and other waste matters of the habitation, over which was erected some primitive form of privy. The institution of middens or the setting aside of some spot for depositing filth and refuse was no doubt a great advance on depositing everything anywhere.

Unfortunately, middens, objectionable as they are, still exist, in some

form or other, in rural districts, and in certain towns. In these places it is attempted to minimise the pestilential odours which arise from them by an admixture of ashes, which to a certain extent keeps them dry and delays putrefaction. The original midden-pit was a hole dug in the ground full of rotting and offensive matter and giving rise to offensive gases and liquids, which only too readily polluted both the soil around houses and the wells near them.

Various improvements have from time to time been attempted upon the old midden-pit, and where these remain, their existence is subject to certain definite rules and conditions. The general rule now is that for the old midden-pit, dug in the ground, should be substituted a small receptacle intervening between the seat of the closet and the floor. The Model Bye-laws of the Local Government Board for the construction of privies and middens in new buildings are to the following effect. The midden or privy must be at least 6 feet away from any dwelling and 50 feet away from any well; ready means of access must be provided for the scavenger, so that the contents need not be carried through a dwelling; the privy must be roofed to keep out the rain and provided with ventilating apertures as near the top as possible; that part of the floor which is not under the seat must not be less than 6 inches above the level of the adjoining ground and moreover be flagged or paved with hard tiles having an inclination towards the door of the privy of ½ inch to the foot, so that liquids spilt upon it may run down outside and not find their way to the receptacle under the seat; the size and capacity of this receptacle may not exceed 8 cubic feet, by which limitation a frequent removal of its contents is necessitated; the sides and floor of this receptacle must be of some impermeable material, the floor being at least 3 inches above the adjoining ground level; the seat of the privy should be hinged, so as to allow of the ashes being thrown in; and the receptacle must be unconnected with any drain or sewer. Middens constructed and maintained under these conditions, lessen the danger of percolation of filth into the soil or of fouling the wells; while the pollution of air is safeguarded to a great extent by keeping the contents in a dry and inodorous condition. No matter how well conducted and supervised, middens are objectionable. Their success depends on proper scavenging arrangements and efficient sanitary supervision.

Tub and Pail Closets.—These are really nothing but middens having a limited capacity, in which the filth-pit is represented by a movable receptacle, such as a tub or pail, placed under the seat for the removal of the excreta. In this system the filth removal is easier and the air pollution less than when midden contents are removed. The pails, whether of wood or of galvanised iron, should have close-fitting lids and be both air- and water-tight. Tarred oak is the best material for making pails, as they last longer and are easily repaired. The structure of the closet in which the pails are used should be similar to that proposed for middens. The pail or tub should be removed at least once a week and a clean one substituted for it. Close-fitting covers should be used during removal of the full pails. There are several modifications of the system. On the "Rochdale" system the pails contain excreta alone, while in some towns the ashes and other dry refuse are added; or the ashes are thrown upon a sifter, so that only the fine ashes fall into the pails upon the excreta while the larger cinders find their way into a separate chamber for further use as fuel. In other places, what is called the Goux system is used, in which the cleansed pails are lined with a dry, absorbent packing of compressed peat or like substance. Nothing but fæces and urine should find a place in these pails, as the absorbent capacity

of the material is limited; the contents should be removed every two or three days and a fresh pail provided. A separate receptacle is used for ashes, house refuse, &c. Sifted coal ashes form very efficient desiccators, but the deodorising effect is very slight. The mixture of coal ashes and excreta usually finds a sale, but the profit is much greater if no ashes are mixed with it. Wood ashes are far more powerful as deodorisers, but it is not easy in this country to have a proper supply.

Neither ashes nor charcoal have the same beneficent and disintegrating action on the excreta as dry earth, hence the use of *dry-earth closets* has become very general. These have a small receptacle, fixed or movable, beneath the closet seat. Clean dry earth, about 1½ lb., is thrown upon the excreta, either by hand, or by automatic delivery from a hopper, every time the closet is used. A constant supply of fine dry earth is needed, ordinary mould being the best, owing to its richness in nitrifying organisms. Sand and chalk are less efficacious. If dried in a stove or over a hot floor, the temperature must not be raised sufficiently high to sterilise it. Earth dried in the sun acts most efficiently. Care has to be taken that each particular stool is covered at once with the earth and no slop water added to the pail contents. The privy or pail-closet system must be regarded as contrary to sound principles of hygiene, wherever facilities exist for any other arrangement; moreover, it involves a heavy initial outlay in buildings and plant as well as an expensive staff to manage it efficiently. If a pail closet has to be used, from a sanitary point of view the earth closet is the very best form, as, if properly managed it is free from smell and the act of removal not offensive. The custom of adding chemical deodorants in order to control the smell is based entirely on a misconception of the process. These inhibit, if they do not destroy, the action of the nitrifying ferment in the earth and render it sterile; there is, therefore, no disintegration and oxidation of organic matter, and the whole process by which the organic substances are destroyed is arrested. It is because of the absence of the nitrifying organisms in such soils as chalk and sand that these soils, being relatively sterile, are not suitable for the purpose. The use of all disinfecting and deodorising powders in earth closets should therefore be prohibited.

The contents of earth closets require no further treatment, and may be applied at once to the land. In agricultural districts, after admixture with fine ashes, the manure from middens and pails may be used on land, but there is always a difficulty of disposing of it to farmers; it is best suited for heavy clay soils.

In some towns where the midden and pail systems are still in use, the crude contents are converted into a dry manure, which can be transported in bags or casks; it is, however, very offensive. In some towns these objections have been overcome by collecting the excreta from the pails and reducing to a small bulk by drying in a closed apparatus, called a concretor, and fixing the ammonia by passage of the fumes over sulphuric acid. By this means the pail contents are reduced to one-twelfth and a valuable manure obtained, which may be either in the form of poudrette or mixed with a little charcoal. In some continental towns, where receptacles capable of holding 50 to 60 gallons of fæcal liquid are placed in the basement of houses, the contents are removed periodically and the contents mixed with sulphuric acid to fix the ammonia. An alternative procedure is to collect the contents of these cesspools in tanks outside the cities or towns, where the liquid part is allowed to evaporate or run to waste into the ground or some convenient water channel, and the solids dried by being spread out on the surface of the land, where it is allowed to accumulate for many months. It

is then sold as poudrette. In spite of statements that this system is not injurious to the workmen or to the neighbourhood, it is undoubtedly offensive and contrary to sound sanitary principles.

LAW RELATING TO CLEANSING AND SCAVENGING.

In England and Wales.—By section 42, Public Health Act, 1875, every Sanitary Authority may, and when required by the Local Government Board shall, undertake or contract for the removal of house refuse and cleaning of privies, ash-pits, &c. Moreover, every urban Sanitary Authority and every rural Sanitary Authority invested with requisite powers may, and when required by the Local Government Board shall, themselves undertake the cleaning of streets; they may also undertake the watering of the same. All refuse, so collected, shall be the property of the Local Authority, to be sold or otherwise disposed of, any profits to be applied to the expenses of the Act in urban and rural districts respectively. Further, if Part III. of th Public Health Acts Amendment Act, 1890, has been adopted in their district, the Sanitary Authority may, under section 26 (2) of that Act, make bye-laws imposing on occupiers duties to facilitate the removal of refuse. Any person obstructing removal to be liable to a penalty not exceeding £5, except as regards refuse, &c., which the occupier intends to employ for his own use, unless he meanwhile suffer it to become a nuisance. If the Sanitary Authority neglect, without reasonable excuse, to remove any refuse within seven days of receiving a remonstrance from the occupier, they shall be liable to pay him 5*s*. for each further day's neglect (section 43, Act of 1875). An urban Sanitary Authority may, by section 45, provide receptacles and places for the temporary deposit of the matter collected.

By section 44, Public Health Act, 1875, the Sanitary Authority has power to make bye-laws imposing the duty of cleansing footways, pavements, ashpits, privies, cesspools, and removing house refuse when they do not themselves contract or undertake to do the same, and may make bye-laws for the prevention of nuisances from accumulations of snow, filth, ashes, &c., and from the keeping of animals. The following is a summary of the Model Bye-laws suggested by the Local Government Board in connection with the terms of this section.

(*a*) *Private Scavenging.*—The occupier of any premises must cleanse the footways and pavements adjoining his premises *weekly*. He must remove the house refuse *once a month*, and excreta at intervals not exceeding the following maximum limits:—

	Must be cleansed at least
Earth closets, with fixed receptacle	once in three months.
" " movable "	once a week.
Privies, whether the receptacles are fixed or movable .	once a month.
Ashpits, whether receiving excreta or not . . .	once a month.
Cesspools	once in six months.

(*b*) *Clearing away Snow.*—The occupier of any premises must clear away snow from the footways and pavements adjoining his premises as soon as possible after it ceases to fall.

(*c*) *Removal of Refuse.*—The refuse from any premises shall only be removed in a suitable covered receptacle or carriage, and if removed from premises within 20 yards of any dwelling, place of business, or public building, only between 7 A.M. and 9 A.M. from November to February, and between 6 A.M. and 8 A.M. from March to October. Refuse must not be deposited upon any road, and any refuse accidentally falling upon a road must be immediately gathered up and the place cleansed.

(*d*) *Deposit of Night-soil and other Refuse.*—No load of filth must be deposited for more than twenty-four hours within 100 yards of any street, dwelling, public building, or place of business. Night-soil deposited for agricultural purposes upon land within 100 yards of a street, dwelling, &c., and not deodorised, must at once be dug or ploughed into the ground.

(*e*) *Keeping of Animals.*—Swine must not be kept within 100 feet of any dwelling, nor cattle where they may pollute water likely to be used for drinking, domestic, or dairy

purposes, or for manufacturing drinks. The same prohibitions apply to storage of dung. Premises wherein are kept any swine, cattle, horses, &c., must be provided with proper receptacles for manure, and with efficient drainage; the receptacle must be water-tight, covered, and entirely above the level of the ground, and it must be cleansed at least once a week; the drain must be properly constructed and kept in order at all times, so as to convey all liquid filth to a sewer, cesspool, or other suitable receptacle.

Ashpits must not be constructed within 6 feet of any dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, nor otherwise in such a position as to entail danger of the pollution of such water. Ashpits must be so placed and constructed as to conveniently allow of scavenging without carrying the contents through any dwelling, public building, or place of business. The capacity must not exceed 6 cubic feet, or such less capacity as may suffice for a period not exceeding one week. The walls must be of flag, slate, or brick, at least 9 inches thick, and rendered inside with cement; the floor must be flagged or asphalted, and raised at least 3 inches above the ground level. The ashpit must be roofed and ventilated, and provided with a door so arranged as to allow of the convenient removal of the contents, and to allow also of being closed and fastened. The ashpit must not be connected with any drain.

If the Medical Officer of Health or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing and purifying thereof would tend to prevent infectious disease, the Sanitary Authority may require the owner or occupier to cleanse, &c., and in his default may themselves do what is necessary (section 46, Public Health Act, 1875).

Section 47 of the same Act prohibits not only keeping swine in dwelling-houses so as to be a nuisance within an urban district, but also suffering stagnant water to lie in cellars or dwellings twenty-four hours after written notice from the Sanitary Authority, and allowing contents of privies and cesspools to overflow or soak out, on a penalty not exceeding 40*s*., and a daily penalty not exceeding 5*s*., after notice, and authorises the abatement of the nuisance by the Sanitary Authority at the expense of the occupier. Moreover, a Sanitary Inspector in an urban district may give notice to the owner of any offensive accumulation of matter, or to the occupier of the premises whereon it exists, to have it removed within twenty-four hours, failing which the Sanitary Authority may remove the same (section 49). An urban Sanitary Authority may give public notice requiring the periodical removal of manure from mews, and other public premises, and enforce the same under penalty (section 50).

In cases where Part III., Public Health Acts Amendment Act, 1890, is in force, by section 27 of the same, the Sanitary Authority have powers for keeping common courts and passages clean, apportioning the expenses incurred to the occupiers of the adjacent buildings. Further, by section 48 of the Public Health Act, 1875, provision is made for obtaining a justice's order for cleansing offensive ditches or water-courses lying near to or forming the boundaries of districts.

In London.—The provisions for cleansing and scavenging under the Public Health (London) Act, 1891, are somewhat more stringent than those of the Public Health Act, 1875, which controls the main actions of Sanitary Authorities in the provinces. By sections 29 and 30 of the London Act, the Local Authorities *must* cleanse streets, footpaths, cesspits, earth closets and privies. They *must* remove house refuse at proper intervals, and trade refuse, also, if required to do so, on payment. As to what is or is not *trade* refuse, shall, on complaint of either party, be determined by a petty sessional court, such decision being final (section 33 (2)). The Sanitary Authority, further, may undertake the collection of manure and other refuse, on request; or may by order require periodical removal by owner (section 36).

Section 16 (2) of the same Act empowers the County Council to make bye-laws (*a*) for prescribing the times for removal of fæcal or other offensive

matter through London, and for providing that the vessel or carriage therefor is properly constructed so as to prevent any nuisance; and (*b*) as to the closing and filling of privies, removal of refuse generally, and as to the duties of the occupier in relation to facilitating the removal of it by the scavengers of the Sanitary Authority. Further, a constable may arrest without warrant and take before a justice any person found committing an offence against such bye-laws, and who refuses to give his true name and address. Swine must not be kept within 40 yards of a street or public place, nor be allowed to stray in any public place. The Court may prohibit the keeping of any animal in any specified place shown to be unfit for the purpose (section 17).

In Scotland.—By the Public Health (Scotland) Act, 1897, there is direct provision, either by bye-law or otherwise, for securing the scavenging or cleansing of the whole or part of a landward district. The Scottish Act follows very closely the lines of the English Acts. Under sections 101 to 123 all sewers are vested in the Local Authority. District Committees can by resolution form special scavenging districts (section 38). Power is also given for the scavenging of highways, &c., within special districts; to purify filthy houses, and for the periodical removal of manure from mews and other premises.

Burgh scavenging and cleansing is fully regulated by the Burgh police (Scotland) Act, 1892, sections 107, 127, 316, which vest the Burgh Commissioners with powers similar to those in force in England and Wales. The occupiers are required to sweep and wash common stairs, and the owners to whitewash and paint them once a year if required by the Sanitary Inspector.

In Ireland.—Section 52 of the Irish Public Health Act of 1878 is the same as section 42 of the English Act of 1875, and contains similar provisions. It practically, however, only applies to urban Sanitary Authorities, as there is no section in the Irish Act corresponding to section 276 of the English Act, which empowers the Local Government Board to invest a rural Sanitary Authority with all or any of the powers and duties of an urban authority.

Under section 54 of the Irish Act (corresponding to section 44 of the English Act) power is given to the Local Government Board for Ireland to require urban Sanitary Authorities to make bye-laws for the prevention of nuisances arising from snow, dust, ashes, filth, &c., and by section 55 the power to provide receptacles for the deposit of rubbish, which in England is permissive and confined to urban Sanitary Authorities, is in Ireland compulsory and entrusted also to a rural Sanitary Authority. The same extension of powers to rural authorities is given as to penalties for keeping swine in dwelling-houses, and for allowing soakage or overflow from cesspools (section 57).

Although section 28 of the Towns Police Clauses Act, 1847, imposes a penalty of 40*s*. for keeping a pig-sty in front of any street, or in or near any street, so as to be a common nuisance, this does not apply generally to urban districts in Ireland, as this enactment is not incorporated in the Public Health Act, 1878, and is incorporated in only a few of the local Acts in force in certain urban districts of Ireland.

In other respects the provisions as to cleansing and scavenging are similar in both the English Act of 1875 and the Irish Act of 1878.

CHAPTER XII

SEWAGE AND SEWAGE DISPOSAL

THE term "sewage" includes not only human excreta, solid and liquid, but also the waste water and impurities from houses and factories. From a hygienic point of view, the excreta are the most important constituents, but besides the excreta and household wastes, sewage contains rain and storm waters, as well as water used in cleansing or sprinkling streets; sewage, therefore, is an extremely complex fluid, varying in the same place from hour to hour both in its volume and its chemical composition. Although the total amount of excretal matter is greater in sewage where water-closets are in use, yet the average composition of such sewage is no stronger than that from towns where there are no water-closets. The reason for this is that ordinary domestic slop or waste water is usually a very foul liquid, and that the existence of water-closets means a plentiful water-supply, which is sufficient to dilute the sewage to as low a strength as that derived from a non-water-closet town. The following table gives the average composition of sewage from towns sewered on the water-carriage system and that from towns using middens :—

Average Composition of Sewage, in Parts per 100,000.

	Total Solids in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
							Mineral.	Organic.	Total.
Midden towns .	82·4	4·181	1·975	5·435	6·451	11·54	17·81	21·30	39·11
Water-closet towns	72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69

The total quantity of sewage depends largely upon the amount of pure water supplied per head per day; in the same manner the solids in solution in any given sewage vary with the quality of the drinking water.

The Removal of Sewage.—There are two main methods of getting rid of sewage from the dwelling—they are the dry and the wet methods. The former has been discussed in the previous chapter, and involves the use of tub, pail and midden closets; the latter implies the existence of a sufficiency of water to carry off the excretal material from the immediate vicinity of the dwelling, and is the procedure to be discussed in this chapter. As to the relative merits of the two methods, no absolute answer can be given in exclusive favour of either. Each is the best under different circumstances. For isolated houses, small villages, and for temporary collections of people, as in camps, the dry method is suitable; its efficient working, however, is dependent upon adequate supervision and the greatest care as to details. Although the initial outlay in closets and sewers is small where the dry method is used, there is the constantly recurring cost of removing the

excreta, as well as of cleansing the pails, &c.; further, some provision has to be made for carrying off slop water, some urine, and possibly a certain amount of liquid trade products as well. The chief objection, however, to the system is the fact that the excreta are retained for some time in or about the dwelling, instead of being removed immediately. For these reasons, the water carriage of sewage is indispensable in towns; its advantages are that it is the cleanest, readiest, and in many cases the cheapest method. The success of this plan depends on there being a good supply of water, properly constructed sewers with good ventilation and proper outfall and means of disposal of the sewer water. The quantity of water necessary to flush sewers and maintain them in a healthy state is about 25 gallons per head per day. If rain-water passes in, it flushes the sewers thoroughly sometimes; but it carries also gravel and *débris*, and may burst the sewers in certain cases, to provide against which storm-overflows have to be provided. The chief sanitary installations connected with a water-

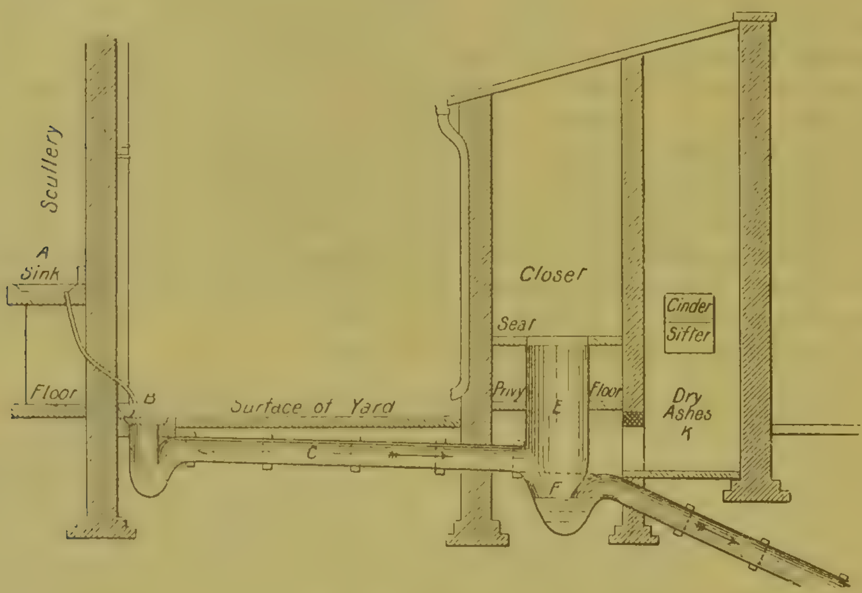


FIG. 66.—SLOP-CLOSET.

carriage system of sewage-removal are water-closets, soil-pipes, drains, waste-pipes from baths, sinks or rain-water gutters, and sewers. We may now consider these appliances in detail.

Slop-closets.—In some towns, particularly in the north of England, where a sufficient water-supply is not available, or where it is not utilised for flushing and washing out water-closets, advantage is taken of the household waste water to do the necessary cleansing.

Such closets are called slop-closets, and of them there are two kinds, viz., those in which the waste water is allowed to run directly into the basin, and those in which, with a view to give a better flush, the waste liquid is collected in a suitable contrivance, called a tipper, and then discharged from time to time in a sudden forcible stream; the latter kinds are called "automatic slop-closets."

The advantages claimed for this class of closets are that (1) on sanitary grounds they appear to be satisfactory appliances; that (2) the trouble arising from frozen pipes and cisterns in the case of ordinary water-closets placed in outbuildings practically need not be considered in the case of slop-closets; that (3) by utilising the slop water of a household for flushing

closets considerable economy is effected in the consumption of water, and the volume of sewage to be dealt with at the outfall is lessened.

The general arrangement of these closets will be readily seen from Fig. 66. The objections to these closets are (1) that the stream of water is not sufficient to keep them clean; and (2) that the back and sides get fouled by the excrement falling against them. For these closets to work properly there should be a fall of at least 5 feet in the drain-pipe communicating with the sewer.

Another form of slop-closet is that in which either a siphon-cistern or tipper is used to collect the slop water and then discharge it in a sudden flush. The tipper is preferable to the siphon tank, as the latter fails sometimes to act owing to clogging with greasy water. A number of these closets can be placed on one drain, a single trap serving for the whole; a ventilation shaft is provided at the upper end.

Improvements on these closets are the various kinds of automatic slop-closets, in which the slow and uncertain trickle of the slop water from the sinks is replaced by a sudden gush of the slop water after storage in either siphon cistern or tipper. The tipper is merely an iron or earthenware vessel, so shaped and balanced on pivots that when full the weight of the contained liquid overbalances it and so causes its contents to be suddenly poured down the pipe. Siphon cisterns being unsuited for the storage of dirty or greasy water, the tipper is practically the better contrivance for this purpose. There are several varieties of these automatic slop-closets; in some the tipper is placed close to the sink discharge-pipe (top flushing), in others the tipper is placed well away from the slopstone, and more or less in a piece with the lowest section of the closet shaft (bottom flushing). The device as to these closets is mainly a question of suitability to any particular place. The tippers, to be effectual, must contain at least three gallons of water for single closets, and five gallons if flushing two or more closets in a row. Some kinds do not have a self-acting tipper, but are discharged by pulling up a handle. Others have the tipper situated at the side or back of the closet basin (Fig. 67).

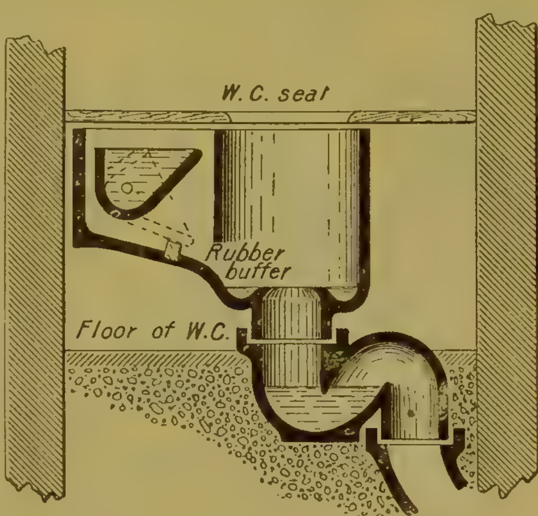


FIG. 67.—SLOP-CLOSET WITH TIPPER.

The various automatic slop-closets appear to be advantageous in that their original cost is small, they consume less water and produce less sewage, and, too, are less apt to freeze or get out of order than the ordinary water-closets; against them are the facts that they are unsightly, less cleanly than water-closets owing to the fouling and lodgment of excreta on the sides; the sewage is exceedingly foul, much fouler than is the case where the closets in use are ordinary water-closets with a clean water flush. This is accounted for by the fact that it is composed solely of the slop water of cottages and the excreta and urine of the inhabitants. The concentrated condition of the sewage, and its tendency to rapid putrefaction, increase the difficulties connected with its ultimate disposal.

The use of slop-closets can only be recommended out of doors, and where the sewers have a good fall, and where a public service of water is laid on

to each house. It is also important that each house should have a separate closet. Subject to these conditions these slop-closets may be of use and value in places where it is desirable to economise the water.

Trough Closets are those in which a long metal or earthenware trough partially filled with water passes beneath the seats of the closets, placed side by side, and receives the excreta from them. These troughs are regularly flushed by the discharge of a volume of water, either by an attendant or automatically by a siphon cistern or tilting receiver, and the contents carried away to the sewer through a trap at the end of the trough. These closets are adapted for schools, factories, and groups of artisans' houses, being little liable to damage by rough usage, or get out of order; the only desideratum being a good large drain well jointed with cement and plenty of water.

Their drawbacks are, original cost, the large quantity of water used, and the alarming noise and splashing which results if the flushing happens to take place when the seat is in use. Trough closets, whether automatic or

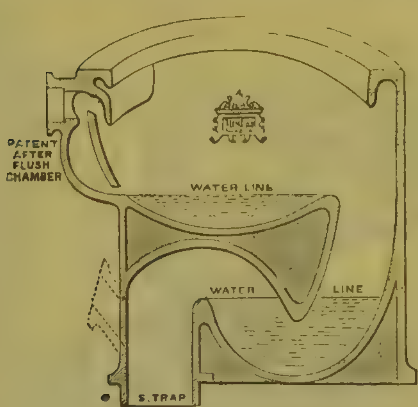


FIG. 68.—WASH-OUT CLOSET.

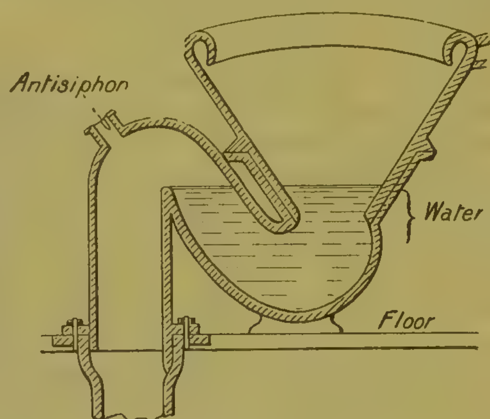


FIG. 69.—WASH-DOWN CLOSET.

otherwise, can only be used where good drains exist and a supply of water is laid on.

Water-closets.—The essential features of a good water-closet are, a basin or other suitable receptacle of some non-absorbent material and of such shape and capacity as to allow the excreta to fall free of the sides and directly into the water in the basin. The area of water should be such as will prevent the fæces from splashing the sides, while the depth from the top of the basin to the water surface should be as shallow as can be made in order that the water may receive the excrement quietly. The seal of the siphon should be at least 1½ inches, but 3 inches is better; the body of the trap should also be made as small as practicable, virtually 1½ pints for a 4-inch outlet and 2 pints for a 6-inch outlet being desirable capacities. All working parts of a closet should be simple, effective and readily accessible.

The type known as the "valve closet" was much in use at one time. By lifting a handle a valve was raised and the mass of water with its contents escaped into the drain; when the handle was lowered it touched a lever which opened a valve on the water main, thereby allowing water to run direct into the basin; this valve closed automatically. There was no cistern and consequently no frost difficulties except in the trap. The objections to this form of closet are that when the handle is lifted it must be done so fully, otherwise there is difficulty in getting rid of the solid matter, and the flush water for the pan is not turned on sufficiently. The valve on the water main, too, causes trouble sometimes, by not working properly. Of

the modern forms of water-closet the common kinds are the wash-out and the short-hopper or wash-down closet. In the wash-out closet (Fig. 68) a certain amount of water is kept in the pan or basin by means of a ridge or dam, over which the excreta are carried by a flush of water. The objections to this closet are, that the water in the basin is not sufficient to cover the excreta, and that the part beyond the ridge and near the outlet is liable to foul from insufficient flushing; in some varieties of this closet the ridge is made too high, with the result that, unless the flush be good, the contents are not at once carried away. A preferable type is the short-hopper or wash-down (Fig. 69) closet, provided with a flushing rim from which the water flows in such a manner and direction that the basin is kept constantly clean. In these forms of water-closets the back of the cone should be made as vertical as possible, so that the excrement drops into the water of the trap and not upon the sides of the basin.

In what are called long-hopper closets, the pan is funnel-shaped and, lending itself to fouling, is less preferable to the shorter type. A later form of closet, and one that is effective in its action, is the "Siphonic" (Fig. 70); in this the pan retains a certain amount of water, into which the excreta are discharged. In addition, the siphon trap is provided with a long ascending arm, so that the water in the trap is at a lower level than that in the pan. The water from the flush is directed not only into the pan, but downwards into the trap as well. As a result of this discharge into the trap, a siphon action is produced whereby the contents of the pan are sucked through the trap into the soil-pipe.

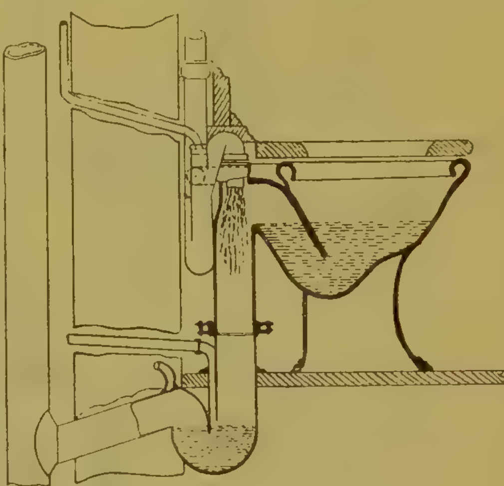


Fig. 70.
"Siphonic" Closet.

The quantity of water required to flush a closet is not less than two gallons; it would be better if three gallons. It must be delivered by a 1¼-inch pipe from a special cistern placed not less than 4 feet above any of these closets. In some modern types, the placing of the flushing cistern close to the level of the top of the basin has been adopted with success, the provision of a larger inlet to the basin more than compensating for the reduction in fall. A great advantage of these so-called "Silent" closets (Fig. 71) is that they are quieter in action than those with cisterns fixed some feet above the basin. This flushing water must on no account be supplied from a cistern or service-pipe which supplies water for household purposes; but each closet should have its own separate cistern. They are usually made of iron, and those with a siphon action are best. A very short pull of the chain will put the siphon in action, when the whole contents of the cistern are discharged. The overflow pipe from the cistern should discharge direct through the wall into the outer air, a few inches from the brickwork; it should under no circumstances be allowed to discharge into any pipe connected with closets.

From time to time efforts have been made to obtain a noiseless water-waste-preventer cistern. Fig. 72 shows one known as the "No Sound." Its noiselessness appears to be obtained by the copper float and valves in the plunger-box. The air-valve remains tight on its seating during the discharge by the buoyancy of the float until the water leaves the latter.

Near the end of the discharge the float falls, which opens the air-valve full bore, allowing air to fill the vacuum, which prevents the gurgling noise so objectionable in most of the ordinary cisterns in use.

Water-closets should always be placed against an outside wall of a building, in which is a window which should open quite to the ceiling. If possible it should be in an outbuilding or in a projection with thorough ventilation between it and the house; the air from the closet should find easy exit to the external air and not pass into the house.

Soil-pipes are pipes for immediately carrying away excreta or sewage from the water-closet to the house-drain. Throughout their course they should be observable, and consequently not be built into walls, but carried

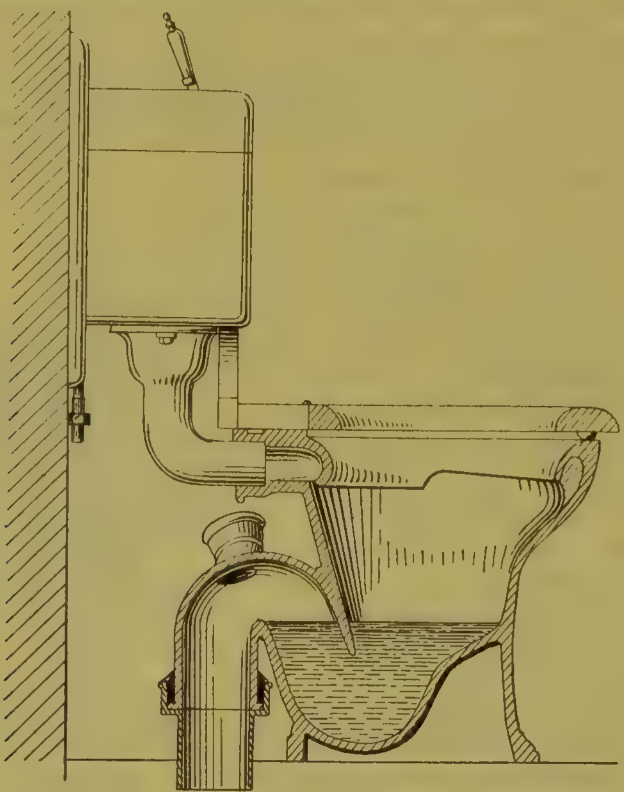


Fig. 71.—"Silent" Closet.

at once outside through the house-wall, immediately beyond the siphon bend or trap of the closet. Soil-pipes should be made of drawn lead, and of at least 8 lb. per superficial foot, and all joints be of the kind known as "wiped." Iron pipes may be used, but must be smooth inside, and protected either by Angus Smith's preservative or coated with a vitreous glaze. In iron pipes the joints must be caulked with lead. A soil-pipe should not be more than 4 inches in diameter, and continued from its highest point well above the roof by a pipe of the same size, without angles or bends, discharging by an opening well away from all windows or chimneys. There is often a misconception in interpreting the term "soil-pipe" in the practical application of this rule, as embodied in bye-laws. Many surveyors construe it to mean the drain which leads directly from all water-closets. The rule is not intended and does not apply to water-closets on the ground floor of buildings as is generally believed, for in such cases no soil-pipe is constructed, but a "drain" only; therefore, the provision of a shaft or pipe to be carried up

to the roof, although required in many cases of this kind by surveyors, cannot be enforced lawfully.

The connection between the closet basin and the soil-pipe is often difficult, as the basin is made of earthenware and the pipe often of metal. Doulton's ceramic joint obviates this difficulty, and a perfect union is formed. The "wiped" joint commonly used cannot always be depended on. Where several closets on different floors discharge into the same soil-pipe, the discharge of water down the soil-pipe may cause unsealing of the traps of the water-closets. This unsiphoning is prevented in the case of the highest closet by the ventilated soil-pipe, but not always so for the lower ones. For these it is desirable to carry a pipe from the highest point of the closet-trap, where it joins the soil-pipe, through the wall into the outer air. Such an anti-siphonage pipe effectually prevents the water being sucked out of the trap of a lower water-closet when the one on a higher floor is being flushed.

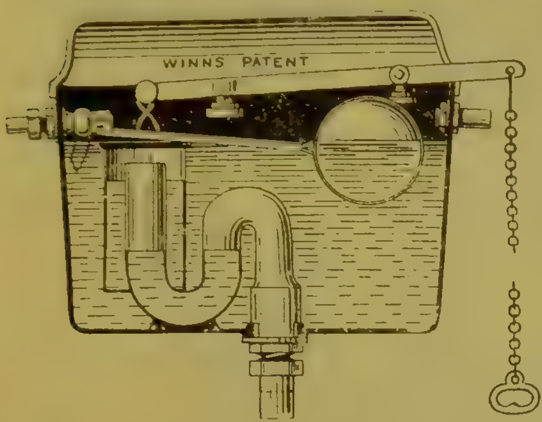


FIG. 72.—"NO SOUND" FLUSH TANK.

The soil-pipe discharges direct into the drain, and at this point it is undesirable to place any trap, as it imposes a useless impediment to the passage of the sewage from the soil-pipe to the drain. Fig. 73 shows a tier of three water-closets fixed one above another. The upper one is a valve closet connected to an anti-D trap, with ventilating pipes to trap and valve-box. The middle one is a wash-down closet, with a ventilated branch soil-pipe. On the ground floor is a siphonic-action water-closet. The whole of the closets are connected to a lead soil-pipe, the branch soil-pipes being fitted with branch ventilating or anti-siphonage pipes. The main soil-pipe is connected by an earthenware rest-bend to the drain, which is supported on a bed of concrete.

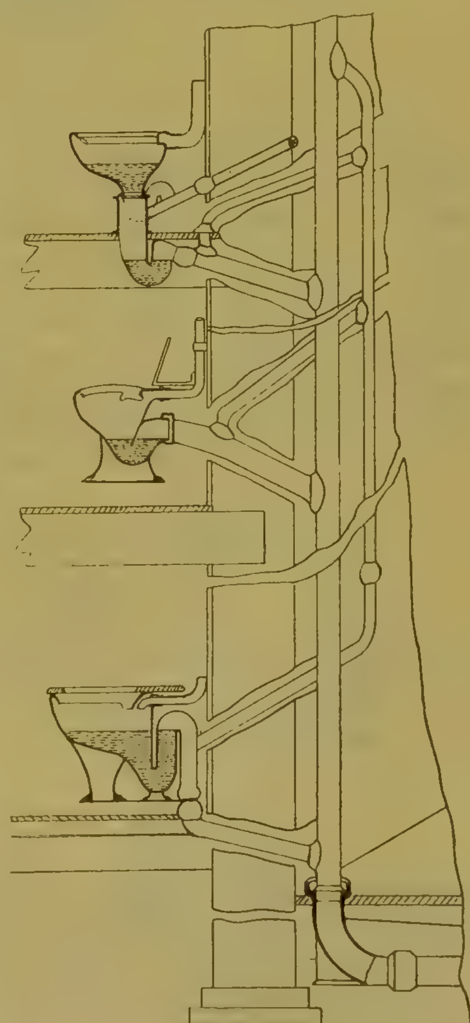


FIG. 73.—SECTIONAL VIEW OF A TIER OF THREE CLOSETS OF DIFFERENT TYPES, FIXED ONE ABOVE ANOTHER.

The House-drain receives, ordinarily, not only the discharge from the water-closets by the soil-pipe, but also rain-water, and waste water from baths and sinks. Its function is to carry away as rapidly as possible to the sewer or cesspit the waste products that are capable of being removed

by the agency of water. In order to do this, it must be made of such a form as will cause the least resistance to the free passage of its contents, and be constructed of materials that will permit of no leakage of surface waters into the drain, or of sewage into the ground; the joints between the different sections must be also made impervious, so that the whole drain is both air- and water-tight throughout its entire length, except at those exits which are provided for the purposes of ventilation.

Drains may be made of either earthenware or iron. They should be laid

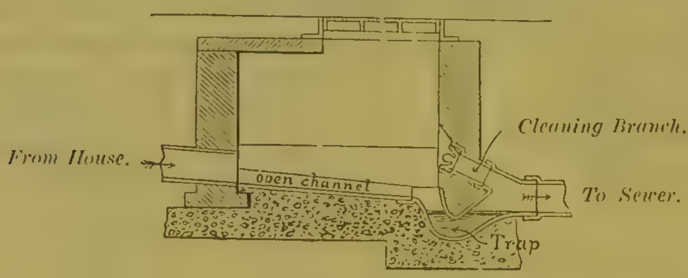


FIG. 74.—DISCONNECTING MAN-HOLE.

in straight lines, each pipe being placed with the spigot and not the socket end directed towards the flow of sewage. The usual size of a main house-drain is 6 inches, but branch drains rarely exceed 4 inches in diameter. Their fall should not be less than 1 in 40 or 60. Small drains are more completely self-cleansing than large ones. Earthenware drains should be laid on a bed of concrete at least 6 inches thick, so as to prevent subsidence, and if carried under a house they should be covered with an equal thickness of concrete. Joints should be made with cement and on no account with clay. Drains made of iron are coming into use; they are certainly preferable to earthenware, as being less liable to fracture, and more readily made water-

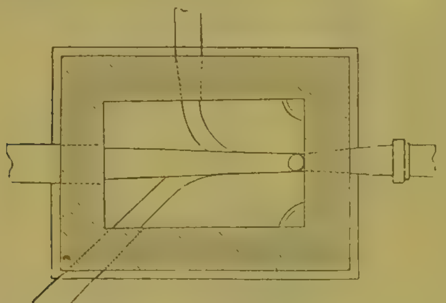


FIG. 75.—PLAN OF INSPECTION CHAMBER.

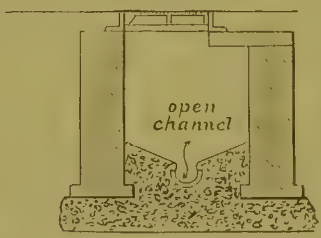


FIG. 76.—SECTION OF INSPECTION CHAMBER.

tight at the joints. Just before the drain leaves the curtilage of a house, and near its junction with the sewer, it should be trapped, and on the house side of this trap an inlet ventilator be provided. This inlet may be placed at the ground level, or a few feet above the ground. The exit for air entering by this inlet is provided by the upper end of the soil-pipe carried full-bore above the eaves. By this arrangement a complete ventilation of the house-drain is secured, and a free escape of any foul gases directed out of doors.

The form of trap intercepting the drain from the sewer is often of a kind shown in Fig. 74, and not infrequently associated with some form of man-hole or inspection chamber. This, if close to the house, is provided with an air-tight cover, the inlet ventilator being arranged at some convenient point.

The man-hole is built of brick set in cement, and in it half-channel pipes convey the sewage instead of complete pipes. Where two or more drains converge to the same point, the location of an inspection chamber or man-hole is desirable, as facilitating access and inspection in the event of any accidental stopping (Figs. 75 and 76).

Traps are used as a barrier to prevent the passage of sewer-air into

Fig. 77.—Siphon Trap.

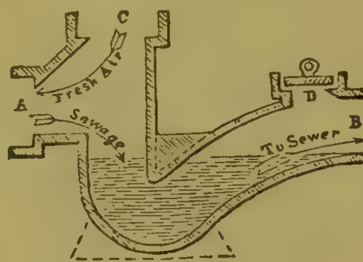


Fig. 78.—Buchan's Trap.

houses. A good trap should completely disconnect the air in one pipe from that in another. This is done by means of a water-seal, which should never be less than to allow the water to stand three-quarters of an inch above the openings. The trap itself should be of such a form as to allow of its being completely washed out with every flush of water passed through it. Traps are of considerable variety, but may be divided conveniently into the siphon, the mid-feather, the flap trap and the ball trap.

The *siphon* trap (Fig. 77) consists of a curved tube, the curve being full of water, which should stand at least three-quarters of an inch above the top of the curve. If two siphon traps succeed each other, one will suck the other dry, unless an air-opening is placed between them; the siphon bend is probably the best and simplest variety of trap. Buchan's disconnecting and ventilating trap (Fig. 78) is often used; it presents a fresh-air inlet, and an opening beyond the water-seal for cleansing; the sewage enters the trap with a considerable fall and the trap is flushed clean. Hellyer's

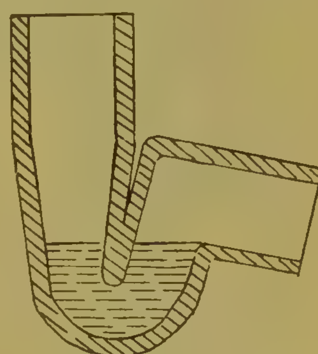


Fig. 79.—Anti-D Trap.

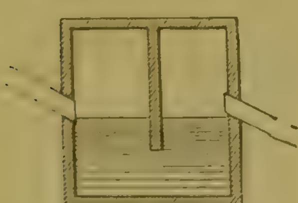


Fig. 80.—Mid-Feather Trap.

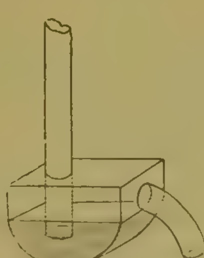


Fig. 81.—D Trap.

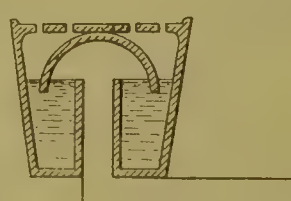


Fig. 82.—Bell Trap.

anti-D trap is an effective device against siphonage. In this trap (Fig. 79) the part which forms the water-seal is smaller in diameter than the in-go, also the out-go is enlarged and square in shape.

The *mid-feather* consists of a round or square box, with an entry tube on one side and an exit tube at the same height on the other; water stands in the trap up to the lower margin of each pipe, and a partition passes down between into the water (Fig. 80). It is a bad form of trap, as it is not

self-cleansing, and fails in all the essentials of a good trap. Another bad form of trap is the D trap (Fig. 81), now rarely seen. The *bell* trap (Fig. 82) is a modification of the mid-feather principle; it is inefficient, as the bell portion is removable, and when taken off the water seal is done away with. The *flap* trap is a hinged valve allowing water to pass in one direction; it was expected that this would prevent the reflux of sewer air, but it has been found to act imperfectly, and is consequently useless. The *ball* trap is one in which a ball rises with the rise of water and closes an orifice; it is a very imperfect form of trap.

What is known as a *knot trap* is shown in Fig. 83. They are made from solid drawn-lead pipes, and although said to withstand siphonage action much better than other types, their cost is somewhat prohibitive. Fig. 84 shows a Jenning's *double-seal* trap; it belongs to the class known as "mechanical traps" much used in America. Inside this trap is a light ball, which falls back into its place after the waste water has been discharged, and thus forms a double seal to the trap. It is questionable whether

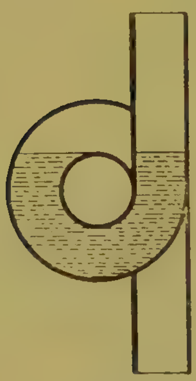


Fig. 83.
"Knot" Trap.

Fig. 84.
"Double-seal" Trap.

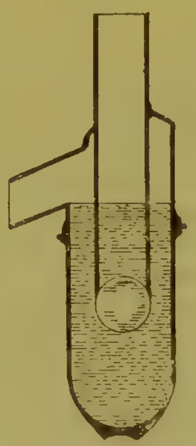


Fig. 85.
"Bower" Trap.

this trap is sufficiently self-cleansing to be quite satisfactory. Fig. 85 shows the *Bower trap*, which is another form of double-seal trap. We doubt the value or advantage to be gained by these devices, as they prevent a true self-cleansing action.

The ordinary form of gully trap is a simple and efficient device so far as the drainage of yards and rain-water pipes are concerned; but it is essential that it be cleaned out periodically. The openings leading thereto should never be below the grating, but all pipes be made to discharge above it. The bye-laws of the Local Government Board require that "the waste-pipe from any bath, sink (not being a slop sink constructed or adapted to be used for receiving any solid or liquid filth), or lavatory, the overflow pipe from any cistern and from every safe under any bath or water-closet, and every pipe in such building for carrying off waste water, to be taken through an external wall of such building, and to discharge in the open air over a channel leading to a trapped gully at least 18 inches distant."

On no account should rain-water or waste-pipes be connected with any soil-pipe or be allowed to act as ventilators to any drain.

The trap as shown in Fig. 86 is in compliance with this bye-law; the gully is fitted with a bucket, which can be lifted out by the handle, so that its contents can be easily removed. The bucket is provided with a flange

round the top, and fits the sides of the trap accurately, so that dirt is unable to pass into it when it is being removed.

To prevent the deposit of grease or sand in the drain-pipe, scullery sinks require to be provided with a grease intercepting chamber; if grease is allowed to flow into the drain, it may gradually stop up the pipe by adhering to the sides, and is then difficult to remove. This chamber is made generally of hollow stoneware, through which cold water circulates, with a tight iron cover, and is ventilated. The hot greasy water from the sink is discharged at the bottom of the chamber, the grease is then cooled and rises to the surface for removal, the sand sinking to the bottom, while the water passes away to the drain (Fig. 87). The grease and sand must be removed every second day or oftener.

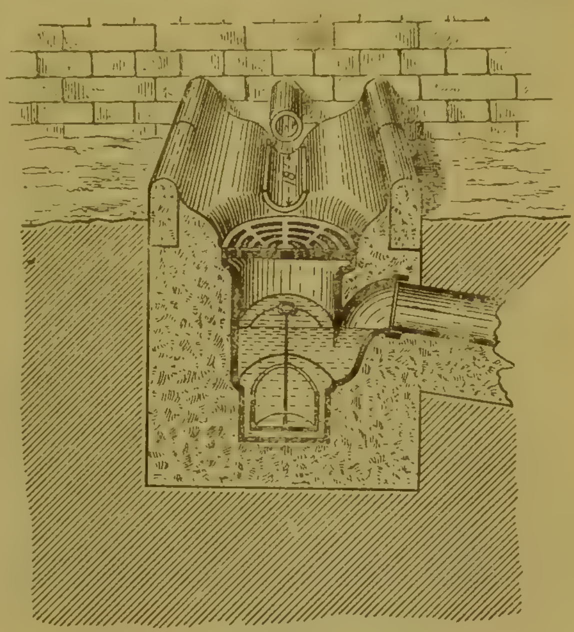


FIG. 86.—GULLY TRAP.

Examination of Drains.—In practice this amounts to the application of certain tests for the determination of soundness. Two chief methods of testing drains are in use, namely, by smoke or volatile agents, and by water. The smoke test consists in filling the drain- or soil-pipe with smoke, the assumption being that this will find its way through any leak or faulty joint, or trap, thus indicating the site of the defect. The smoke may be forced into the pipe or drain from a pumping apparatus, or be produced within the drain from a specially prepared grenade or rocket. An alternative procedure is to pour a tablespoonful of peppermint oil, mixed with hot water, either down the highest water-closet or down the pipe at the highest point available; as this is a very volatile and pungent oil, there is no difficulty in tracing where the odour is emitted, and so detecting the leak. Although convenient for testing traps and fittings above ground, these tests are of little value in the examination of underground pipes. The only absolutely trustworthy test for drains is the water test. Having plugged up the lower end of the drain by a suitable water-tight stopper, the drain is filled gradually with water. If the water-level remains constant for half an hour or more, the drain may be considered sound and water-tight. If it will not fill, or the level falls rapidly after filling, there is leakage somewhere, and it will be necessary to open it up and repair, or perhaps relay.

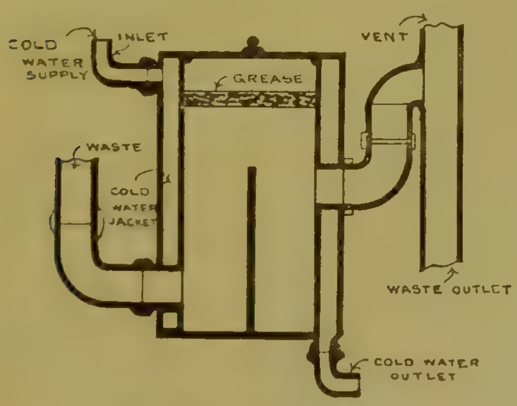


FIG. 87.—GREASE TRAP.

In applying the water test to drains, it must be remembered that each foot of water-head exercises a pressure within the pipe or drain of 0·432 lb. on the square inch, or to find the head of water required to obtain any given pressure

this, in pounds per inch, if multiplied by 2·31, will give the head in feet. It is doubtful whether, in the routine examination of drains, a greater head of water than from 2 to 3 feet need ever be employed. If stoppage of the drain occurs, and there are man-holes and access pipes provided, the spot where the obstruction takes place can be localised easily; but if no such arrangement exists, the drain or pipe will have to be broken in one or more places, until the point of stoppage is found. A brisk flushing with water will generally remove any obstruction. Stoppage may be caused by imperfect laying of the drain, by improperly finished-off joints, so that a rough surface is left on the inside of the pipe; or roots of trees may find their way through the joints of earthenware pipes, when clay is used for jointing. The most frequent cause of stoppage, however, is that various articles are improperly thrown down the water-closet, and gradually fill up the pipe.

Sewers are the trunk canals into which the house-drains empty their contents. Unfortunately, the two terms "drain" and "sewer" have been used loosely and confusedly. By section 4 of the Public Health Act, 1875, a "drain" is defined as meaning any drain of and used for the "drainage of one building only," or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed. "Sewer," on the other hand, includes sewers and drains of every description, except drains to which the word "drain" interpreted above applies, and except drains vested in or under the control of any authority having the management of roads and not being a Local Authority under the Act. From these definitions it follows that when two or more houses have a common drain, that drain is, within the meaning of the Act, a sewer, and, as such, vested in the local Sanitary Authority for its proper cleansing, ventilation, and repair, under sections 13 and 15 of the Public Health Act, 1875. These, however, are not the interpretations which have been placed upon the expressions "drain" and "sewer" in all cases, as the situation is complicated by the Public Health Acts (Amendment) Act of 1890. By section 19 of this Act, which, however, is only an adoptive Act, and therefore not in force in every district, we find that where it is in force the definitions of the 1875 Act are considerably modified; so much so that, if two of the houses belong to the same person, the combined drain is a sewer, and repairable as such by the Local Authority; but if the two houses belong to different owners, then this combined drain is a drain under the Acts, and any expenses of repair are to be borne by the owners in due proportion. The section 19 of the 1890 Act speaks of a "single private drain," and the whole difficulty seems to hinge on what this expression really means; it is unfortunate that the Act does not define it. Certainly the judgments in specific cases, given in the Courts, have not rendered the point any clearer. In a recent case * it was laid down that where two or more houses are drained by a single pipe, neither the fact that the pipe is wholly situate on private land, nor the fact that the houses belonged to different owners, will suffice to make the pipe a "single private drain" within the meaning of section 19, so as to entitle the Local Authority to require the owner (under section 41 of the Act of 1875) to amend the same.

The verdict of the Court of Appeal in another recent case † being also on the question of the meaning of a "single private drain" under particular circumstances, created a fresh anomaly, and to a lay mind appears a curious decision. From this case it appears that the owner of certain houses had

* Thompson *v.* Eccles Corporation.
† Jackson *v.* Wimbledon Urban District Council.

been called upon to pay for certain repairs to a pipe which ran in the rear of several houses and received the drainage of each, but which joined another pipe at right angles, which latter pipe discharged into the public sewer in the roadway. The pipes in question were situate on private property. The result of the case was that the " common drain " was decided to be a "sewer," whilst the pipe connecting this common drain with the sewer remained a " single private drain " within the meaning of section 19 of the Act of 1890. We have, therefore, under this ruling, two sewers (the public sewer and the " common drain ") repairable by the Local Authority, connected by a " single private drain " repairable by private owners. The cases quoted may be taken as good examples of the many drainage cases which are continually coming before the Courts. In all instances, in everyday work where any system of combined drainage is involved, special attention should be given to the legal aspect, so that, if possible, litigation may be prevented, and an equitable arrangement arrived at between all parties interested. It is hoped that the existing unsatisfactory state of drainage law will soon be amended.

The system of sewerage now generally adopted in England is the " combined " system ; in this system the surface drainage and rain-water are carried off by the same channels as the sewage. Sometimes separate channels are provided to carry off the rainfall ; this is called the " separate " system, and involves two sets of channels ; one to carry off the rain and storm waters, the washing of streets and open spaces ; the other to carry off the sewage. The former discharge their contents into the nearest river or watercourse ; the latter will convey the sewage to be treated in some one of the methods to be described subsequently. The advantages claimed for this are that smaller sewers are required, and that the amount of sewer water is less, richer in quality, and more regular in flow ; no storm waters enter the sewers to flood the lower districts of a town, and no road detritus is washed into the sewers. The disadvantages are that separate channels have to be provided, and rain-water washes away much that would pollute a stream ; the scouring effect of rain on sewers is also lost, but this is a doubtful objection. Adoption of either plan must depend on local circumstances.

In every system of sewerage two objects are generally aimed at ; first, sewage has to be removed, and this should be done by impervious pipes, such as glazed earthenware or iron, or brickwork laid in cement, or even pure concrete ; and secondly, when necessary, the subsoil must be drained. This may require pervious drains or drain sewers. If pipe sewers only are used, the subsoil water remains unaffected, except so far as a small portion may find its way along the channels formed by the pipe. Sometimes pervious drains of earthenware are laid down to carry off the subsoil water. Brooks of Huddersfield has combined in one system a drain and sewer, in which there is an arrangement for subsoil drainage under the sewer itself.

Sewers up to 18 inches diameter are generally made in earthenware or iron and are circular in section. Larger sewers are also made of iron, or of brick lined with cement, or of pure concrete ; when iron pipes are used they should be coated with Angus Smith's preservative to prevent erosion. If fluctuations in the amount of sewage are great, an egg-shaped sewer is preferable to the circular form ; but if there is sufficient sewage to keep sewers constantly running, say half full, the circular section is best, being cheapest and strongest. If earthenware pipes are used, it is advisable to lay a foundation of concrete, which supports the pipes in their length, and not at the sockets only. The joints must be cemented, and not puddled with clay, care being taken that the cement does not get inside the pipes, forming projections

in the sewer, against which solid matters will lodge and obstruct the flow of the sewage. Stanford's joint is composed of 1 part of boiled tar, 1 part of clean sand, and 1½ parts of sulphur; this forms an excellent cement.

To avoid deposition of sediment, sewers should be laid in as straight lines as possible and with a regular fall; junctions should be made oblique, so that the sewage may enter in the direction of the flow. The junction of drains is made by a special form of pipe, which may be either single or double. If the sewer curves it should describe a wide sweep, the radius of the curve not being less than ten times the cross-sectional diameter of the sewer. Inspection of pipes may be provided for by a man-hole or by a disconnecting trap.

Main sewers are generally made of well-cemented brickwork and egg-shaped in form, to give greater hydraulic depth, and, therefore, increased velocity with a small quantity of fluid. The egg-shaped sewer is formed by two circles touching one another; the diameter of the upper circle equals twice that of the lower, so that the invert is the narrowest part. This form of sewer secures the maximum scouring effect with the minimum quantity of

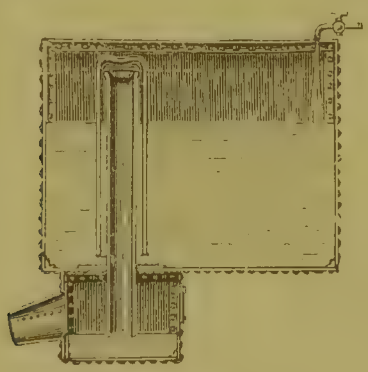


FIG. 88.
AUTOMATIC FLUSHING TANK.

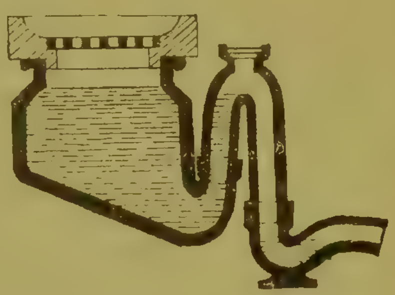


FIG. 89.
FLUSHING GULLY.

water. To secure a uniform flow, it is necessary to diminish friction as much as possible; and this is found to be least in this form of sewer, as the wetted perimeter is proportionately reduced, instead of being, as in every other form, relatively increased. The interior should be smoothly finished, and the sewer itself quite impervious and free from any inequality.

At each principal change of line or gradient there should be arrangements for inspecting, flushing, and ventilation; at all junctions and curves the fall should be increased to compensate for friction; the principal sewers should have special overflow pipes for any excess of rainfall; no junctions should be at right angles, nor opposite other junctions; tributary sewers should deliver in the direction of the main flow, and should have a fall into the main at least equal to the difference between their two diameters; pipes of small size should always join on to pipes of larger size; if the tributary joins the main sewer below the level of the sewage in the latter, deposits are produced in the branch. Street gullies are generally provided to prevent the entry of gravel and solid matters into sewers. The *débris* collects in the gullies, while the water flows off by an opening to the sewer placed on a higher level, and the deposit is removed at intervals.

The amount of fall that should be given to sewers, or the inclination at which they should be laid, will depend upon the velocity of the current that it is desired to attain. To prevent deposit in pipes of 6 and 9 inches in diameter, the velocity should not be less than 3 feet per second; for 12 to 24

inch pipes, $2\frac{1}{2}$ feet; and for larger ones 2 feet per second. These velocities would require a fall of from 1 in 140 to 1 in 200 for pipes from 6 to 9 inches in diameter, and of 1 in 400 to 1 in 800 for pipes from 12 to 24 in diameter, and for larger sewers 1 in 244 to 1 in 784 according to size. The fall should be equable without sudden changes in level.

In some cases a fall is almost impossible to obtain, as, for instance, at Southport, in Lancashire, where the ground is nearly a dead level. The fall there is about 1 in 5000, and never exceeds 1 in 3000. In such a case the drain would have to be cleaned either by locks or flushing-gates to retain a portion of the contents for a time, and then set them free suddenly in order to flush the next section, or by special arrangements, such as Field's flush-tank (Fig. 88). Sometimes these tanks are used for collecting and automatically discharging into sewers the sink and laundry waste waters of large establishments; this is an unsound practice, as they are apt to fail through clogging. For such purposes, a better form of flush is obtainable by the use of Adam's flushing gully (Fig. 89).

The simplest formula for calculating velocity of flow through sewers or pipes is the following:—$V = 55\sqrt{D \times 2F}$, where V is the velocity in feet per minute, D is the hydraulic mean depth, and F is the fall in feet per mile. Then, if A be the sectional area of the current of fluid in feet, VA is the discharge in cubic feet per minute.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. The "hydraulic mean depth" is the section area of current of fluid divided by the wetted perimeter. In circular pipes it is always $\frac{1}{4}$th the diameter, whether running full, half full, or otherwise.

In egg-shaped sewers, the hydraulic mean depth varies with the volume of water flowing through them, but in sewers constructed on the usual plan, where the transverse diameter is $\frac{2}{3}$rds of the vertical, the hydraulic mean depth is as follows:—

Running full,	transverse	diameter	× 0·2897
$\frac{2}{3}$rds full	,,	,,	× 0·3157
$\frac{1}{3}$rd full	,,	,,	× 0·2066

The "wetted perimeter" is that part of the circumference of the pipe wetted by the fluid. In an egg-shaped sewer under these three conditions it equals the transverse diameter multiplied by 3·9649, 2·3941, and 1·3747 respectively.

Ventilation of Sewers.—In well-constructed sewers, where there is no deposit and the sewage is allowed to flow away without any obstacle to the outlets, the air is much better than might be expected. This point has been discussed on page 144. The few micro-organisms present in the air of sewers, compared with the external air, is explained by the tendency these have to be deposited on the damp surfaces of the sewers; the few that are present in sewer air are related to those in the outside air and not to the micro-organisms in the sewage, as in the absence of splashing and bursting of gas bubbles, the sewage micro-organisms do not become disseminated readily in the air of the sewer. Pettenkofer long ago pointed out the distinction between sewer air, which is generally without smell and harmless, and sewer gas, which is always the result of stagnation, deposit and putrefaction; certainly recent experiment shows the necessity of making this distinction.

Sewers cannot be constructed air-tight, on account of the very numerous openings into them; the tension of the air is generally not very different from that of the atmosphere outside, while the movement of the air is usually

in the direction of the flow of the current. Certain conditions, however, are present which produce movement of the air in sewers, the chief being—the variation of temperature in the sewer and in the external air, barometric pressure, the passage of hot water from houses or manufactories, causing a rise of temperature in the sewage and consequent expansion of the air in the sewer, the blowing-off of steam, which increases the temperature and pressure suddenly, and the sudden increase of water flowing into the sewers. Any of these conditions may expel air from the sewer or draw air in from the external atmosphere. Tidal water in sewers is not so liable to cause violent movements of the air in them, because the rise of the tide is gradual.

The simplest plan for ventilating sewers is by means of a shaft from the crown of the sewer to the surface of the street or road above, where it is covered by an iron grid. The mud and gravel which may fall through the grid is caught in a tray placed beneath the grating, but which allows the free passage of air around it. One such opening is placed commonly at intervals of a hundred yards or so. This system has been subjected to much criticism, mainly on account of the fact that it favours the discharge of objectionable gases from sewers more or less immediately under the noses of passers-by. As a routine practice, this plan of open ventilating grids at road levels is to be discouraged. If sewers need ventilating, a preferable method is to locate along their course at suitable intervals tall iron shafts, provided with rust pockets, and carried sufficiently high as to permit of the escape of air and gases at a level well above the roofs of houses. As a matter of fact, however, if sewers are well constructed, have sufficient fall and flush of water, obviating the local accumulation of decomposing material, there should be no accumulation of foul gases. These ideal conditions, however, are not always existent; in which cases the only way to cope with the nuisance from sewer emanations is by abolishing dead-ends of sewers or ventilating them, by erecting pipe ventilators in substitution of offensive gratings at street level, by the pan-siphon trapping of offensive street gullies, and the free admission or circulation of air in the sewers. The latter detail will do good by favouring oxidation of any putrescent matter and by diluting any offensive gases evolved. Recently, an agitation has been started to solve this question of sewer ventilation, by advocating the abolition of the intercepting trap on the house-drain between the sewer and the house, thereby converting every house-drain and the soil-pipes discharging thereto into so many sewer ventilators. The main objection to this proposal is that it would destroy the drain isolation, which is now possible, of each house from the rest of the houses of a district. Moreover, as we cannot rely absolutely upon the soundness of every sanitary fitting in individual houses, the risks of sewer gas gaining direct access into dwellings would be considerable. It is true the intercepting trap is not an ideal sanitary appliance, but we have to choose between two evils, namely, having sewer gas laid on to the house, or having the efficiency of the house-drain somewhat interfered with; and the latter is the lesser evil. Until we can secure perfectly laid sewers, with adequate fall and ample flush of water, we must ventilate, and probably the location of vertical shafts, discharging above the level of the houses, at suitable intervals, constitutes the better remedy.

Pneumatic Methods of removing Sewage.—These are practically three in number, namely, the Liernur, the Berlier, and the Shone systems. That proposed by Liernur has been employed for some years in places on the Continent where, owing to the situation, any fall for sewerage is not possible. There are two sets of pipes or drains; the one,

pipes of small diameter, being used for waste water from houses and factories; the other, of cast-iron pipes, 5 inches in diameter, is connected with the closets, and carries away the excreta from closets and bedroom slops. It is intended that the contents of the former should be allowed to flow at once into any river or stream, as it is only slightly polluted, solid matters having been separated first by strainers, or, if necessary, by filtration. The sewage proper is conveyed by the larger or second set of pipes to small reservoirs or tanks placed at intervals under the streets or roadways; these are made to connect with larger tanks, which again communicate with a central reservoir at the sewage works. The water-closets are connected with a receptacle or siphon tank in the basement of the buildings or houses; these tanks are themselves coupled up by means of the larger pipes with the various tanks under the roadways. A vacuum, being produced by an engine working an air-pump at the central works, extends through the whole series of pipes; these are fitted with stop-cocks, and the contents of the house tanks and street reservoirs are sucked into the central one, from which it is pumped out and disposed of on to land or made into poudrette. The extracting force is said to equal a pressure of 1500 lb. per square foot, which is sufficient to draw the excreta through the tubes with great rapidity; the vacuum or extraction is usually put into action twice a day, or sometimes only once in a day. This system has the disadvantage of not disposing of waste and slop waters, for the removal of which special conduits are required. There is also the possibility of the pipes being clogged with fæcal matter, and it is impossible to disconnect the house-pipe from the reservoir by an efficient trap. The system, is, moreover, somewhat complicated, and does not work automatically, but only at stated times, when the vacuum is established, hence the excreta are not removed from houses at once. A successful installation has been working for some years at Stanstead, in Essex, and for low-lying districts, where suitable sewer gradients are difficult to secure, this system offers considerable prospects of success.

The Berlier system is very similar in principle to that of Liernur. The soil-pipe, which is generally 6 or 8 inches in diameter, and of cast-iron, opens at the lower end into an iron vessel called a *receiver*, within which is an ironwork circular basket, with the iron bars far apart, in which all hard substances and foreign bodies are retained. Whatever leaves the basket is in a fit condition to travel along the pipes without giving rise to any danger of obstruction. From the bottom of the receiver, the sewage passes into the *evacuator*, to which an exhaust is attached at the bottom. When the evacuator is full, the valve opens and the contents are drawn into the exhaust-pipe. This system works automatically, which is an improvement on the Liernur plan.

The Shone system acts by means of compressed air, and is worked usually from a central steam-engine. This plan is not applied to water-closets, but is a device for raising sewage from one level to another when the ground is flat and a proper fall cannot be secured. The sewage is received into "ejectors," which are cylindrical reservoirs placed beneath the level of the ground and, after a certain quantity has entered, act by means of a float on a counterpoised lever opening a valve and admitting the compressed air, which forcibly ejects the sewage into the further length of the sewer-pipe, or to an outfall direct. The compressed-air tubes are conducted along the upper flat outer surface of the reservoir; the arrangement is carried out by valves acting automatically, which permit of the escape of the expanded air as well as the admission of the compressed air. This plan is especially useful when the ground is flat, and where it is difficult to get a fall.

DISPOSAL OF SEWAGE.

The difficulty in the system of removing excreta by water really commences at the outfall.

This difficulty is felt in the case of the foul water flowing from houses and factories without an admixture of excreta, almost as much as in sewer water with excreta. The exclusion of excreta from sewers, as far as it can be done, would not solve the problem—would, indeed, hardly lessen its difficulty. In seaboard towns the water may flow into the sea, but in inland towns it cannot be discharged into rivers, as this practice is prohibited by the Rivers Pollution Acts of 1876 and 1890. Independent of the contamination of the drinking water, sewage often kills fish, creates a nuisance which is actionable, and in some cases silts up the bed of the stream. It requires in some way to be purified before discharge. At the present moment the disposal of sewage is the sanitary problem of the day, and it is impossible to be certain which of the many methods may be finally adopted. It will be convenient to describe these proposals.

Discharge into the Sea.—This method consists of the direct discharge of the sewage at ebb tide, so as to carry out the sewage to a distance from the shore, and diffuse it into the sea before the tide begins to flow. Where tidal currents exist, the point of discharge should be situated below the place in the direction of the falling tide and not above it.

The greatest difficulty with such outfalls is at low water. As the flow of sewage in sewers towards the outfall is continuous, the best method is to conduct the sewage into a tank or reservoir, where it can be stored, and discharged into the sea at suitable states of the tide. Sewage should not be discharged into tidal estuaries, as it is never carried any great distance away from the shore, owing to currents and the rise of the tide; the sewage is very frequently taken back and deposited near the outfall or on the foreshore. This system is only available for a limited number of places situated near the sea coast, and cannot be employed for the disposal of sewage of inland towns.

The Cesspool System.—This system must be regarded only as temporary and partial; it provides for the immediate removal from the house of the excreta and foul waters, but only to a short distance, where it is received into a cesspool, which has to be emptied from time to time. Cesspools are constructed generally of brick, and in the majority of cases the solid matters only are retained, the liquids passing into the surrounding subsoil and infiltrating it for some distance around. In some cases the cesspool is lined with cement, so as to be more or less impervious, and in this case an overflow-pipe must always be provided.

The cesspool or dead-well is really the only method available in a country place. In this system the tank can never be quite water-tight, therefore the surrounding soil gets polluted, and the water-supply must not be derived from anywhere near; the amount of percolation depends largely on the nature of the soil. Cesspools should be placed at least 50 feet distant from any dwelling, and 100 feet from any well, spring, or stream. They should always be at a lower level than the well from which the drinking water is taken, so as not to pollute the saturated portion of the permeable stratum above the well. They should be ventilated and emptied at regular intervals; it is often found convenient to utilise the liquid contents by distributing this over the gardens or adjoining fields, and for this purpose a small hand-pump is usually attached, connected with a distributing pipe or

channel. Complete disconnection by proper traps and efficient ventilation are necessary to make this a sanitary method.

Disposal on to Land.—The utilisation of land as a medium for the reception of sewage has been accomplished in a variety of ways, and under certain conditions can be made to fulfil the twofold purpose of purification and disposal. Sewage is passed on to land either in its crude state or after some preliminary straining, or after clarification and the precipitation of its grosser suspended matter by some one of the chemical or other methods of treatment to be described later. The application of sewage to land is conducted on one or other of two methods, namely, irrigation or filtration.

In *irrigation* schemes, the soil must have a gentle slope and be drained by subsoil drains placed about 5 or 6 feet deep, by which the effluent can be conveyed to the nearest watercourse. To ensure success, the area must be sufficient and the sewage passed on at intervals, so as to permit of aeration of the soil. The land is laid out in ridges and furrows, and the sewage made to reach it in as fresh a state as possible, also freed from its coarser material by settlement or precipitation. Although sewage farms of this nature are not a commercial success, still immense crops of coarse grass can be obtained from them. Under favourable conditions the purification of the sewage is excellent, the chief disturbing factors being frost and excessive rainfall. For dealing with sewage by this method, a large quantity of land is required—about 1 acre for the sewage of 300 persons.

Land *filtration* of sewage may be either upward or downward; the former is now practically abandoned as being totally inefficient. The process of filtration is essentially one of oxidation and nitrification, while intermittency of application is a *sine quâ non*, even in suitable soils; hence the process is commonly spoken of as intermittent downward filtration. The action of the land is also mechanical. As regards the soil itself, the physical conditions, porosity and fineness of division, have more to do with its cleansing power than its chemical composition. The best soil seems to be a loose marl, containing hydrated iron oxide and alumina. The conditions necessary for the successful filtration of sewage through land are:—(1) a porous soil; (2) an effluent drain not less than 6 feet from the surface; (3) proper fall of land to allow the sewage to spread over the whole land; and (4) division of filtering area into four parts, each part to receive the sewage for six hours, and to have an interval of 18 hours. The quantity of land required is about 1 acre to purify the sewage of 1000 persons, and the larger solid bodies should be removed by screening or straining before allowing the sewage to flow on to the land. When the amount of available land is limited, the sewage may be treated first by precipitation, before allowing it to flow on the land, but this will deprive it of much of its manurial value. If the sewage be treated previously, 1 acre of land will suffice to receive the sewage of from 2000 to 5000 persons.

The effluent is excellent after filtration through land, if the details of the process have been carefully carried out, and is quite fit to be discharged into any river or stream. The solids form a fine cake on the soil surface, and can be broken up readily and worked in by digging or ploughing. Apart from the action of vegetation, the purifying effect of different soils shows considerable variation. The Rivers Pollution Commissioners found that a cubic yard of chalk or sand effectually purified 5·6 gallons of sewage per diem applied intermittently; while a sample of loam, under the same conditions purified 9·9 gallons. Peat had little purifying power at first, but improved with repeated use. Intermittent filtration through suitable soil

removes 70 per cent. of the organic nitrogen and 80 per cent. of the organic carbon from sewage; but on the whole it may be said that peat and stiff clay lands are generally unsuitable for the disposal of sewage.

Their use for this purpose is commonly attended with difficulty, and where the depth of top soil is only some few inches, the area of such lands required to secure efficient disposal and purification would be so great as to render land treatment impracticable. When properly carried out, disposal on to land, either without or with some preliminary treatment, is a valuable method, but it will be readily understood there are distinct limitations to its utility. Experience shows that with careful management, a properly constructed and well-conducted sewage farm can be carried out without nuisance or injury to the health of the surrounding population; but if the land becomes water-logged from either original unsuitability or inattention, grave nuisance may result.

PURIFICATION OF SEWAGE.

This presents great difficulties, and many methods have been suggested and tried with varying success. For the complete purification of sewage, three processes are involved:—first, clarification; secondly, an alteration of the chemical composition of the organic putrescible matter in solution in sewage, whereby it will not undergo any further putrefactive changes; thirdly, the removal of disease-producing bacteria. These results are not obtained equally by the various methods which have been proposed. The more important are the following:—land treatment, chemical treatment, and biological methods. The first-named or land treatment has been discussed in the preceding section, when considering the final disposal of sewage on to land, and we find it more or less intimately associated with both the other two methods of sewage treatment. We need not here allude to it again in detail.

Chemical Treatment.—The processes suggested for the purification of sewage under this head are mainly precipitation methods. The procedure consists in collecting the sewage in tanks, thus allowing a large volume to remain comparatively quiescent, so that the solid particles subside. To accelerate the process, the sewage in the tanks is mixed with some chemical agent or precipitant. The solids formed, in settling, take down with them the suspended matters in the sewage, together with some of the dissolved organic impurities; the proportion, of course, varies with the amount of solid matters precipitated. The effluent from the tanks then flows at once into a river or stream, or may be passed over land, or be filtered through it. A large number of methods have been suggested, but it is proposed to mention only those which have been reasonably successful.

One of the principal substances used for precipitating or clarifying sewage is lime. The quantity employed depends on the character of the sewage, and varies from 6 to 15 grains of quicklime for each gallon of sewage. If the effluent is made alkaline by the addition of too much lime it undergoes putrefaction rapidly; it has been attempted to prevent this by adding chloride of iron to the quicklime, by which means purification is delayed but not prevented; the process is simple and cheap, but as the organic matters in suspension only are acted on, it has failed to produce either a valuable manure or the purification of the offensive liquid. Precipitation has little effect on the removal of microbes, pathogenic or otherwise.

Among other processes which have been tried in different places may be mentioned those which employ lime and alum, lime and sulphate of iron,

alum and iron as "alumino-ferric," also the Amines process, and the ferrozone and polarite filtration method. In London, a chemical process has been applied to the sewage before its discharge into the sea. This consists in adding 3·7 grains of lime and 2·5 grains of sulphate of iron to every gallon of sewage; it produces an average reduction of 18 per cent. of dissolved oxidisable organic matter.

The Amines process consists in mixing herring brine (3 grains) with lime (30 to 50 grains per gallon), and passing the volatile matters so produced, composed of amines and ammonia, into crude sewage, which, it is said, is completely sterilised by this means. The clarification is very rapid and complete, and a heavy, nearly inodorous sludge, which does not become putrescent, is produced.

In some places, polarite or magnetic spongy carbon has been used as a filter for sewage, the solid and some of the dissolved material being first precipitated by ferrozone or magnetic ferrous carbon.

All these precipitation or so-called chemical processes do, to a certain extent, purify sewage, chiefly by removal of suspended matters, but leave a large amount of putrescible matter in the effluent, and produce considerable quantities of precipitated material, known as sludge. This sludge possesses very little manurial value, and is composed chiefly of the organic and mineral matters precipitated from the sewage, and contains usually about 90 per cent. of water. When pressed in a filter press the amount of water is reduced to between 40 and 50 per cent.; these cakes of sludge are subsequently ground into powder and used as manure. The liquid which is expressed from the sludge is very impure and has to be treated later on in the same way as the original sewage. It is an exceedingly strong and odorous liquid. The composition of the pressed sewage sludge at Crossness is stated to be:—water, 58 per cent.; organic matter 17 per cent.; mineral matter, 25 per cent.

The effluents produced by these precipitation or chemical processes are fairly satisfactory; there is very little suspended matter, and a very large proportion of the organic constituents are precipitated or retained in the sludge. If passed into a river or stream in which the volume of water is large, they are readily disposed of without creating nuisance or silting up the bed of the river. In some cases it has been found necessary to filter the effluent, through coke or other filters, before discharging it into a stream. In other cases the effluent is passed on to land, but it has little or no manurial value.

Webster proposed to purify sewage by electrolysis. The chemical action which takes place in sewage when it is electrolysed depends chiefly on the fact that water as well as the chlorides of sodium and magnesium are split up by the electric current into their constituent parts, chlorine and oxygen being set free at the positive pole, and uniting to form hypochlorous acid: this being intensely active, and liberated in a nascent state, oxidises the organic matter in the sewage into innocuous compounds, as well as attacking the iron plates, forming hypochlorite of iron; at the negative pole, potash, soda, magnesia, ammonia, &c., are set free. Cast-iron plates are used as electrodes, and give the best results. The effluent produced by this process contains about 3 grains per gallon of suspended matters, which consist almost etirely of oxide of iron. It is filtered subsequently through filter-beds of sand and coke, and passed on to land if this is convenient, as it has a certain manurial value. The sludge is dug into waste land or shipped out to sea.

The treatment of sewage with electrolysed sea-water was the basis of the

Hermite process, and has lately been revived in what is known as the oxy-chloride method. In this latter procedure, ordinary salt water replaces sea-water. The result is a liquid disinfectant, containing hypochlorites and free chlorine, which is almost odourless and inoffensive. It is claimed for both these processes that sewage, when mixed with these liquids, is rendered practically inert and sterile. We have no experience of the oxy-chloride, but we know that Hermite water, which contains from 0·5 to 0·6 gramme of chlorine per litre, is very destructive to all traps and metal fittings. Neither process is suited for general use in buildings, but rather for flushing defective sewers, or de-odorising and sterilising clarified sewage. The original Hermite water was somewhat unstable. In the oxy-chloride process this defect has been overcome by adding caustic soda to the electrolysed fluid, whereby probably a stable double salt of magnesium and sodium hypochlorite is formed.

Biological Methods.—Strictly speaking, the passage of sewage on to and through land is a biological method of treatment, inasmuch as it aims at, and more or less secures, a destruction of sewage as sewage, and a building-up of new substances in its place by means of the organisms normally present in the sewage or in the land through which it is made to filter. Until recent years, land filtration was the only biological method of treating sewage available or practised. The difficulties associated with the securing of sufficient suitable land led to a closer study of the problem, and the development of new applications of the biological treatment of sewage has been a striking feature of recent sanitary effort. These new departures depend essentially upon bacteria contained in the sewage itself, and are based on the principle that organic changes in sewage are due mainly to bacterial action, and aim at fostering and assisting these changes by placing the sewage under the most favourable conditions for undergoing disintegration and oxidation by means of micro-organic life. Practically, they are the direct antithesis of all methods of treating sewage by chemicals, which, being for the most part antiseptic in action, modify and largely neutralise the vital action of the bacteria present in sewage. The micro-organisms existing normally in sewage may be said to consist broadly of two classes, namely, the "anaerobes" or those which exist without oxygen, and the "aerobes" or those to whom oxygen is essential. To those of the first group falls the main share of the work of breaking down, digesting, and liquefying the solid organic matter of sewage, whereby it is reduced to simple chemical states, chiefly ammonia; while on those of the second group devolves the duty and work of oxidising, mineralising, or nitrifying the ammoniacal substances into nitrites and nitrates.

The actual changes which take place in sewage, as the result of bacterial action, are somewhat complex and obscure, but they have been described aptly by Rideal as consisting mainly of three stages.* In the first stage, or that of anaerobic liquefaction and preparation by hydrolysis, the albuminous matters, cellulose, and fats are broken up into soluble nitrogenous compounds, fatty acids, phenol derivatives, gases, and ammonia. In the second stage, or that of semi-anaerobic disintegration of the intermediate dissolved bodies, a further formation of ammonia, nitrites and gases takes place. In the third stage, or that of aeration and nitrification, ammonia and carbon residues are changed into water, carbon dioxide, and nitrates. A large variety of installations have been devised to secure these really natural or biological changes in sewage; though they differ from each other in matters of detail, they all are the same in principle. As representing the most typical and

* Rideal: *Sewage and Sewage Purification*, 3rd ed., London, 1906.

possibly the best we may consider those suggested by Scott-Moncrieff, Cameron, and Stoddart.

The Scott-Moncrieff installation consists of a liquefying or digesting chamber, filled with large stones and open at the top. The sewage entering at the bottom, though a restricting chamber, passes upwards and onwards continuously, but sufficiently slowly to be acted upon by the anaerobic and liquefying organisms, which form colonies in the nidus formed by the stones, and which, under the favourable conditions presented to them, increase in proportion to the work required of them. The result is, that the solid organic matter is liquefied, and an effluent, which is practically without solids in suspension, passes on. This is the first stage. The second stage is conceived with a view to place the liquid sewage under such favourable conditions that the nitrifying and aerobic organisms would multiply similarly to organisms of liquefaction, and complete the process by nitrification. The arrangement adopted (Fig. 90) consists of a series of trays containing filtering media (coke, fine coal, or stones) placed one above the other, and with intervening air spaces a few inches in depth between them. The series are in duplicate, and the sewage is delivered over the surface of the upper trays alternately by means of a tipping trough. The liquid passes slowly downwards

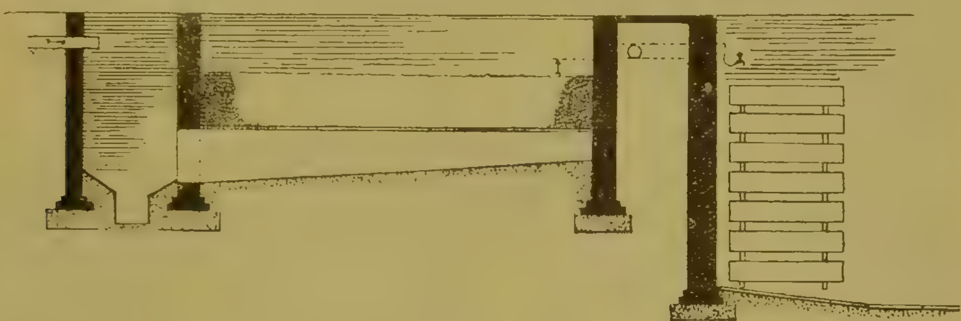


Fig. 90.
Sectional View of Scott-Moncrieff's Sewage Installation.

through the various trays in the form of a slow but heavy dropping rain, meeting, under the most favourable conditions of the aeration, the organisms of nitrification, and finally passes away to a stream or on to land. We have had opportunities of examining a number of effluents from one of these installations, and found them to be remarkably clear, free from smell, wonderfully stable, and exhibiting very high degrees of nitrification and purification.

The installation first suggested by Cameron is sometimes called the septic tank system. In it the sewage is led first into a tank from which air and light are excluded. Digestive changes take place in the sewage within this tank as the result of anaerobic bacterial action, which is favoured by the darkness, the absence of fresh air, and the perfect stillness at which the sewage is maintained. Under these influences much of the solid matter is rendered soluble and dissolved. After remaining twenty-four hours in the tank, the sewage is drawn off without disturbing the scum layer on its surface, and passes away in a thin stream along an open trough or aerator, over the edge of which it flows into automatic tippers, which ultimately discharge it on to filter-beds. At this stage the sewage appears as merely dirty water having comparatively little offensive smell, and, running along and over the trough, becomes largely aerated by exposure to the air. The filter-beds consist of clinkers and coke breeze, in which the aerobic and nitrifying organisms attack the sewage constituents and complete the work of organic disintegration

commenced in the septic tank. The filters are filled, and the sewage distributed on to them by an automatic gear. Each filter-bed takes six hours to fill, remains full for six hours, is emptied in half an hour, and aerates for eleven and a half hours. Filtrates or effluents derived from installations of this kind, and which have been brought under our notice, have been bright, clear, and stable. In this process, the action of the anaerobic organisms is encouraged by the special construction of the tank, and carefully differentiated, as in Scott-Moncrieff's method, from the subsequent aerobic action, due to other organisms, in the filters. The periodical resting and aerating of the filter-beds helps obviously to maintain the activity of the aerobic bacteria (Fig. 91).

It is clear that in these ordinary filter- or bacteria-beds as mentioned above, and which are flooded intermittently with sewage and then allowed to rest

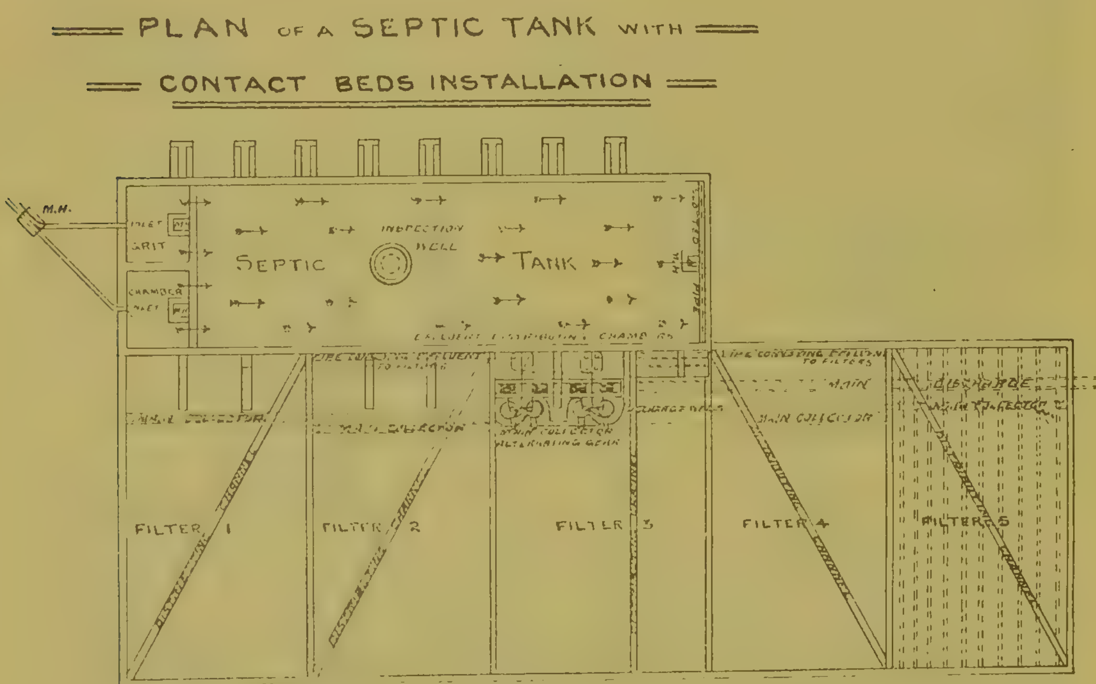


Fig. 91.

Diagram Illustrating the Treatment of Sewage by Cameron's System.

or aerate, the different reactions or activities of bacterial species are somewhat fortuitously confused and reversed according to the periods of filling or rest. The objections to this condition suggested the employment of continuous filtration of sewage through a coke- or breeze-bed. A continuous bacterial filter-bed of the simplest description is that suggested by Stoddart. This filter is not intended to deal with crude sewage, but only with sewage which has been treated previously, either by precipitation or by anaerobic bacterial action. The filter consists merely of a mass of coarse rubble, clinker, ballast, coke or other material placed on a concrete floor, laid with sufficient fall to cause any liquid that reached it to flow towards the nearest external surface; sometimes the filter-bed may be surrounded by retaining-walls similar to those of the contact or intermittently filtering beds of Cameron and Dibdin; but the absence of impermeable retaining-walls favours the free aeration of the filter; its depth may be anything from 1 to 12 feet. The essence of Stoddart's method is continuous filtration through the bed, and not intermittent filtration as in Cameron's installation. In order to

maintain the continuous filtration with the maximum of efficiency, it is considered essential that the sewage should be applied over the whole upper surface of the filter in fine streams of drops at such a rate that the maximum amount shall be passed without charging any part of the filter with visible liquid. This even distribution of the sewage over the filter can be secured by one of the many types of revolving sprinklers or by the patent distributors of Stoddart ; each of these consists of corrugated iron, presenting alternate ridges and gutters. The ridges are notched by V-shaped openings at regular intervals. A series of vertical points is placed beneath the lower surface of each gutter by driving nails through the bottom, down and over which the sewage trickles as it overflows the edge of the notches. The chief advantages claimed for this continuous filtration are the extreme simplicity of construction and management, the relatively small area of bed required, and the extraordinary rapidity with which sewage may be passed through the filter with the production of a satisfactory effluent. A filter of this kind, composed of material such as clinker of not less size than 1 inch diameter, measuring 100 square yards and 4 feet deep, can deal with 80,000 gallons of strong sewage every day.

It must not be supposed that these three systems exhaust the list of biological methods which have been suggested for treating sewage ; they represent merely three types of installation. There are many others which have met with varying degrees of success, but all are based upon the principles which have been explained, involving some form of preliminary treatment of the sewage by solution of the suspended solids in either a digestive or detritus tank, and followed by aeration and oxidation by passage through one or more contact- or filter-beds. Modifications of the septic tank system have been worked successfully, using an open septic tank and double filtration through bacterial filter-beds, or, as they are often called, first and second contact-beds ; but no matter what particular form the modification takes, it will be found generally to have reference to one or more of the following details of construction or working, namely (1) size and arrangement of the digestive tank ; (2) depth and nature of the filtering material ; (3) method of distributing the sewage upon the filters.

Among the more original and striking modifications of these biological installations are those depending mainly on active aeration, of which the chief are Lowcock's, Waring's, and Ducat's. In all sewage, the processes of nitrosification and nitrification are dependent on the amount of oxygen available, so much so that to nitrify 1 gramme of nitrogen in 20 litres of an effluent about 10 litres of air, or 15 litres of fully aerated water, will be needed. A further quantity of oxygen is demanded by the carbonaceous matters, measured approximately by the "oxygen-consumed" figure. This explains the comparative failure of many filter-beds, especially if the fluid is a raw sewage or a merely screened or precipitated effluent without preliminary hydrolytic change, as with every 100,000 gallons of sewage about 8000 cubic feet of air must be continuously supplied, and even then oxidation is apt to be slow, irregular, and incomplete. Contrivances like cascades and weirs can only raise the dissolved oxygen to the saturation-point of about 7 c.c. per litre, or 112 cubic feet per each 100,000 gallons.

To meet this difficulty, Lowcock suggested the forcing of air through filter-beds at a mean pressure of $4\frac{1}{2}$ inches of water. In installations at Malvern and Wolverhampton, the air forced through sand and coke breeze-beds bore no relation to the volume of liquid which flowed continuously through the beds. The results showed a purification of the tank effluent applied to the filter of 76 per cent., calculated on the organic ammonia, and

68 per cent. on the oxygen absorbed.* The recent practice of resting these filters for twelve hours each day tends, however, to show that natural aeration is necessary to the smooth working of the system, and amounts to little more than a modified reversion to the process of alternate fillings, or intermittent working.

Another instance of continuous filtration assisted by forced aeration is that suggested by Waring for treating the sewage of Newport in America. The combined sewage of this city became frequently mixed with sea-water, the effect being an increase of the suspended solids by precipitation of soap and other matters, a result frequently noted in tidal estuaries and contributing to the formation of mud banks and other siltage masses. The sewage, after passing through a grit-chamber, was pumped alternately through either side of a divided tank containing a shallow bed of broken stone to arrest the coarser solids. The liquid next passed slowly through four straining tanks filled with stones and gravel, whose function was said to be "mere mechanical sedimentation." When these became clogged, a plug was released and the sludge emptied into an aerating tank filled with stones and gravel, where air was driven constantly through the mass, and as soon as active bacterial action had set in, the sludge was rapidly dissolved. Air was also forced through the straining tank till it was again in condition for use. A number of other installations on the same or slightly modified lines have been constructed in various places in the United States, but we question whether with satisfactory results. The action is apparently entirely aerobic, and unaccompanied by previous hydrolysis, except what would occur in the sewers.

In what is known as Ducat's method, the sewage is run, without any preliminary treatment, on to an aerated filter, constructed in the following way :—A chamber 8 feet in depth, and varying in area according to the amount of sewage to be dealt with, is constructed with a cemented platform, and with walls composed of agricultural drain-pipes, all built in as "headers" and sloping downwards slightly towards the interior. The walls, of course, are strengthend by piers at intervals according to their lengths. The bottom courses of the walls consist of header bricks built open so as to allow a free passage for the liquid to run out into a channel constructed all round in the cemented platform. The filter-bed is formed of a layer of large stones, above which are several layers of coke, each about 18 inches in depth, which are separated by thin layers of large stones to give aeration. The top portion of coke is large, that below decreasing in size in succession. In this way a bed 8 feet deep is formed. The sewage is applied as finely as possible over the whole surface of the bed by distributing troughs placed 1 foot apart and having notches in the sides from which the sewage rains down on the bed, and is thus presented in a favourable way to the organisms thriving in the presence of oxygen. The distribution of the sewage may also be made by tipping troughs, which cause the sewage to fall in splashes over the surface, and this method is adopted in the latest installations.

This filter, arranged in the manner explained, forms an excellent nitrifying bed, but it affords no opportunity at all for effecting biolysis in stages. It would seem that, bearing in mind the advantages of providing arrangements to facilitate the two very distinct stages of liquefaction and nitrification, any system which aims at combining a liquefying and a nitrifying bed in one must be under certain disadvantages. In any circumstances, the sewage must be carefully screened before passage on to a filter of these types. In

* Lowcock: various papers in *Proc. Instit. Civil Engineers*, 1893 and 1897, vols. cxi. and cxv.

the various successful installations of the kind which have come under our notice, the sewage had travelled long distances through sewers and appeared to have lost much of its solid nature by bacterial action in the sewer itself, so that the clogging material was in a great measure absent.

A conspicuous difficulty attending the processes aiming at the direct oxidation of sewage by currents of air is the cooling produced, which in winter may actually result in freezing. To avoid this, several inventors have introduced systems of artificial warming, with an additional object of stimulating the bacteria. Ducat provided a series of hot-water pipes for heating in winter, while the same idea was applied by Whittaker and Bryant in their "thermal aerobic sewage filter" at Accrington. The plant included an open septic tank, the effluent of which was distributed over a filter-bed of 2 feet broken stones, and 6 feet gas coke, with 12 inches of limestone chippings on the top, by means of an automatic revolving sprinkler. A small jet of steam was blown into the sewage just as it arrived at the sprinklers, thereby raising the sewage and the whole body of the filter to the required temperature. The added heat also promoted the circulation of air in the filter, so that better aeration was claimed to be produced in this way. Installations of this kind have not come into general use owing to their costliness, both for original laying out and maintenance. The effluents yielded have been good.

When the biological treatment of sewage was first introduced it was assumed that a relatively short stay in the digestive or septic tank would lead to a more or less complete solution of the suspended solids and a removal of the sludge difficulty. Prolonged experience has shown this to be far from the case, as the majority of digestive tanks and even filter-beds also lose in the course of a few months from 50 to 30 per cent. of their cubical capacity owing to the deposition of undigested solids. The recognition of this fact, particularly in the case of septic tanks, where the deposition of sludge is often considerable, has led to a variety of suggestions as to their size and construction. The most favourable size for these tanks is now held generally to be equal to one day's average flow of sewage, but in some successful installations it is found to be considerably more, and in others much less. To avoid the undue washing over of this sludge and scum from the digesting tanks on to the filters, the introduction of scum-boards has been advantageous, but even in regard to this detail, absolute uniformity in method and result has not been secured. We find precisely the same state of affairs in regard to the filter-beds. There is no unanimity of opinion as to whether the beds should be worked on the contact, that is, intermittent, or the continuous system; whether there should be single, double or even triple contact-beds; of what size and material the filtering material should be, or how the sewage should be best delivered on to the filters. On each and all of these points there is much divided opinion, varying from the advocation of simple slate slabs separated by 2-inch spaces,* to the insistence of the filtering matrix being composed of material of $\frac{1}{8}$-inch fineness.† The same is the case in regard to the depth of the filter-beds; some show excellent results with beds only 3 feet deep, others insist that the best working depth is anything from 4 to 10 feet.

Dibdin's suggestion, advocating the use of slate *débris* supported on suitable slate blocks for furnishing a matrix, appears to offer a reasonable

* Dibdin: "Sewage Disposal, with Special Reference to Improvements in Primary Contact-beds," *Sanitary Record*, July 12, 1906. See also *Journal of the Society of Chemical Industry*, May 1906.

† Reid: *Further Evidence on Fine-grain Percolating Filters*, Report to Staffordshire County Council, August 1906.

hope of minimising the sludge problem, as the extra space available doubles the working capacity of the bed, and at any time the accumulation of silt may be flushed from the slates and the bed restored to its original condition as new. The detritus washed off the slate slabs is found to dry inoffensively when exposed to the atmosphere, and to assume a condition resembling ordinary mould. An installation of this kind at Devizes has dealt with the whole of the unscreened and unsettled sewage of that town satisfactorily, and, by combining in one slate-filled tank the double effect of the earlier digesting tanks and contact-beds, marks a distinct step towards simplification. If it can be applied on a large scale we shall have arrived at a satisfactory advance towards the solution of the detritus problem. The effective working of this type of tank-bed appears to be a cycle of one hour filling, eight hours contact or holding up, and three hours for emptying and aeration. The main difficulty in the case of large installations seems to us to lie in an economical washing-out of the slate-bed with flush water.

In attempting to draw any definite conclusions as to these points, we must remember that the three essential factors in the final changes desired in sewage are time, air, and micro-organisms; and, given a sufficiency of air, the greater the number of organisms present the larger the amount of work done, provided the organic matter of the sewage is brought into intimate contact with the organisms. The factor which governs the bacterial population of a sewage filter-bed is the area available for growth, and this may be increased either by enlarging the cubic capacity of the filter or by subdividing the filtering medium. Therefore, we may make this generalisation that, whether it be for a contact-bed or for a continuous filter, the finer the matrix the less need be its depth, and *vice versa*; to this we may add, as the outcome of experience, that primary contact-beds need to be made of coarser material than secondary or tertiary beds. While micro-organisms play the larger part in the conversion of organic matter in sewage into a stable form, recent work suggests that there is a concurrent physical action by which suspended matters are arrested in the filter-beds, and matters in solution are fixed; this appears to be due to an adsorptive power inherent in the matrix material. During periods of aeration, the bacteria decompose the fixed matters and regenerate the adsorptive function of the filtering material. Dzierzgowski * has shown that organic matter is fixed energetically in a direct ratio with the complexity of its molecule; thus, the nitrogen of albumin is fixed more energetically than that of peptone, the nitrogen of peptone is fixed more readily than that of asparagin, while ammoniacal nitrogen is only feebly retained. Glucose and starch are not fixed at all. Dunbar has shown that methyl violet, when placed in contact with slag, is fixed, and disappears in two hours without the intervention of bacterial action. It is probable that quite one-third of the organic nitrogen in sewage is fixed in the material of a filter-bed as the result of a physico-chemical action, as distinguished from the effects of micro-organisms.† The quantity of sewage which contact-beds may be expected to purify will depend upon the nature of the sewage and the amount of preliminary treatment it has undergone. Assuming that the sewage has been treated previously by chemical precipitation, or by subsidence, or in a septic tank, the general view is that 750,000 gallons can be treated per twenty-four hours on an acre of contact-beds, allowing for periods of rest, but not for secondary treatment. Allowing one acre of secondary bed for every two acres of

* Dzierzgowski: *Gesundheits ingenieur*, 1907, Nos. 1 and 2.

† Calmette: "Sur la mécanisme de l'épuration Biologique," *Revue d'Hygiène et de Police Sanitaire*, 1907, vol. xxix, No. 6, p. 496.

primary bed, we can say that about 500,000 gallons per acre per twenty-four hours can be finally treated by this system.

As to individual systems, we cannot dogmatise ; a type of installation which yields excellent results in one place may not do so necessarily in another. The requirement of each and every place must be determined by local circumstances, and no hard and fast rules can be laid down as to whether a system of contact-beds or a continuous filter installation is the better. With a weak sewage, a much greater volume can be treated per square yard by sprinklers than on contact-beds. Where the sewage is strong it should be first treated on a contact-bed, and for final purification on a percolating filter. Unsedimented sewage should never be passed on to the percolating or sprinkling filters, as the distributing arms speedily choke and a colloidal matted growth forms on the surface of the bed, which impedes aeration. Strong-smelling or putrefactive sewage should not be treated by revolving distributors or fixed sprays, as the odour is intensified by this mode of distribution. As regards matrix for filter-beds, favourable reports are made as to ligno-carbon, a manufactured product from peat, otherwise hard clinker from gasworks or from refuse destructors for primary filters, and coke or pan breeze for secondary filters appear to be the most suitable and readily obtained material. If the sewage is free from manufacturing effluents of injurious character, and if a sufficient area of suitable land can be obtained in a convenient position at a reasonable cost, then irrigation is probably the most rational and economical method of treatment. Many kinds of manufacturing refuse, if admitted into sewers, interfere with the efficacy of land filtration, either by clogging the soil or checking chemically the process of oxidation ; this latter condition operates prejudicially also in biological methods. In these cases, a preliminary purification by precipitation is necessary, and it is probable that different forms of chemical treatment will be found necessary for effluents of different trades.

In all cases, the principle to be aimed at is the immediate and complete removal of all kinds of refuse from the vicinity of habitations in the most expeditious manner. The dry methods do not answer this requirement, as the excreta are only removed at intervals, and although deodorisation may be complete, disinfection is not attempted. For a large population, therefore, some system of water carriage is necessary. Having, therefore, sewage to deal with, we must get rid of it in the least objectionable manner. It must not be sent into rivers ; therefore, where land is available, immediate application to the land, by irrigation or filtration, is indicated. By land filtration, sewage can be purified so that the effluent water may be permitted to run into any stream or river, the water of which is not required for drinking purposes. Little, however, of the manurial value is saved, the greater part passing away in the effluent. Irrigation accomplishes all that is done by filtration, with the further advantage that the whole of the manurial constituents of the sewage are returned to the soil, which is fertilised by them. Both systems are, however, often impracticable owing to lack of suitable land.

As regards the biological treatment of sewage, it can now be stated definitely that the average results are as good as those given by well-managed sewage farms, while the best results are a long way better than those recorded of any sewage farm. A most important feature in the biological treatment of sewage as compared with any chemical process is that, when properly carried out, it yields an effluent which is incapable of secondary putrefaction. In this respect it may be regarded as the best solution of the sewage problem, because the stability of an effluent which has been

mineralised by a biological process is absolutely secure. We feel convinced that biological methods of treating sewage are not only scientifically correct, but sufficiently efficient and economical in their working as to quite preclude any reversion to artificial methods, such as treatment by chemicals or electricity. In formulating this opinion, we would emphasise the paramount need of the biological treatment of sewage being carried out logically and scientifically, and with due regard to the fundamental principle that it needs to be conducted in three stages :—(*a*) settlement and screening-out of the grosser solids ; (*b*) anaerobic decomposition in the septic or digestive tank ; and (*c*) oxidation on bacteria-beds. In the management and successful working of these beds, the following points are of the first importance. The bed should be worked very slowly at first, in order to allow it to settle down and the bacterial growths to form. In this way there will be less danger of suspended matter finding its way into the body of the bed, while the material is still loose and open. The work thrown on the bed should not be increased until analysis of the effluent reveals the presence of surplus oxygen, either dissolved or in the form of nitrates. Analysis of the air in the bed may be made usefully from time to time during resting periods. The variations in capacity should be recorded carefully. If the capacity is found to be decreasing rapidly, a period of rest should be allowed. Long periods of rest should be avoided during winter, as when deprived of the heat of the sewage the activity of the organisms decreases. If necessary, the burden on the bed should then be decreased by reducing the volume of sewage applied daily, rather than by exaggerating any intermittency of working. The insoluble suspended matter should be retained on the surface by covering the latter with a layer of finer material, not more than 3 inches in depth. The suspended matter thus arrested should not be raked into the bed, but when its amount becomes excessive it should be scraped off. This should be done, if possible, in dry warm weather, after the bed has rested some days. By placing the outlet and inlet penstocks as close together as possible, the suspended matter will tend to concentrate in their vicinity, and its removal be facilitated.

What form biological installations for sewage treatment will take ultimately it is difficult to say ; but the present tendency inclines towards the use of shallow continuous filters, some 3 feet deep, and having a matrix of fine material, rather than contact-beds. With this view we are disposed to concur, but at present it is impossible to lay down hard and fast rules ; local circumstances must be taken into account and each sewage judged on its inherent qualities.

Though bacterial or biological systems are important advances in the treatment of sewage, especially in destroying and rendering the organic matter soluble, the resulting effluents are teeming with microbial life—in fact, in this sense, are little different from the original sewage. Moreover, we know that specific and pathogenic bacteria do survive passage through these installations, and can find their way into the resulting effluents. Houston's observations on this point, made for the Royal Commission on Sewage Disposal, are of interest and of importance. In these experiments, *B. pyocyaneus* was added deliberately to sewage, both at Hendon and at Leeds ; at the former place as the sewage flowed on to a continuous filter of the Ducat type, and at the latter place as it flowed into a septic tank preliminary to contact-beds. In the case of the continuous filter-bed, *B. pyocyaneus* appeared in the effluents within *less than ten minutes* from the start of the experiment, and was present, at first invariably, later at irregular intervals, up to the tenth day. In the case of the septic tank and contact-bed,

B. pyocyaneus appeared in the septic tank liquor *within two and a half hours* from the start of the experiment, and in the contact-bed effluents at the earliest possible times—that is, the first emptying of the bed. The organism was recovered from both septic tank liquor and from the contact-bed effluent as late as the ninth day. These are very striking results, and suggestive that effluents from biological installations are by no means free from danger, if discharged direct into running streams. For this reason it is usual to pass all effluents from biological sewage installations either on to land or through a special sand filter before allowing them to gain access to a stream. Provided such stream is of reasonable volume, and taking into consideration the remarkable natural purification of water which occurs as the result of the action of light, movement, and sedimentation in a flowing river, we question whether this precaution of always passing sewage effluents, after biological treatment, on to land is altogether necessary. We cannot hope to obtain a sterile effluent, and there is no evidence to show that even after passage through land the final effluent is free from objectionable micro-organisms. We think sufficient safeguards exist for the public health if the water authority filters its water when drawn from rivers, irrespective of whether it received an effluent or not higher up. At the present time, however, the question of the relation of sewage disposal to the pollution of various estuarial waters and the shell-fish industry raises issues of great economic importance quite apart from the sanitary aspect of the question. In such cases, the value of the industry, together with the difficulty of protecting the beds in any other way, has raised the serious consideration of the question whether it is possible to render effluents safe by some kind of sterilisation. An experimental study of certain kinds of sterilisation methods has been made both in America and this country; among the various methods proposed we find heat, lime, acids, ozone, copper, the permanganates, and chlorine or its compounds. In the greater number of these methods, the expense attaching to their use renders their practical application on any large scale prohibitive.

Among the possible agents for use in the sterilisation of sewage effluents, chlorine, either as chloride of lime or as free gaseous chlorine, appears to afford the most reasonable chance of success consistent with economy. The efficiency of chloride of lime as a disinfectant has long been known, and the earliest attempt to apply it to the sterilisation of sewage effluents appears to have been made by Thresh at Ilford. The addition of 140 to 200 parts of the chloride per million was found to give a nearly sterile effluent after the latter had flowed in a closed conduit for a mile.* Assuming commercial chloride of lime to contain 35 per cent. of available chlorine, the amount of this gas used was from 50 to 100 parts per million of effluent. Experiments made at the experimental sewage station of the Massachusetts State Board of Health in 1905-6 show that neither the addition of large amounts of bleaching-powder, up to 100 parts of available chlorine per million, nor the storage of the effluent for periods of time up to twenty-four hours, proved entirely effectual. It is, further, shown that a concentration of about 5 parts per million of available chlorine and a storage period of about two hours give practically the maximum efficiency possible with the process as indicated by a destruction of 99·96 per cent. of the total bacteria. The estimated cost of such treatment is four shillings per million gallons of effluent.†

* Thresh: *vide* evidence given before Royal Commission on Sewage Disposal and Treatment, 1902, question 8917.

† Phelps and Carpenter: "The Sterilisation of Sewage Filter Effluents," *Sanitary Record*, 1907, vol. xl. pp. 96, 112, 156, 181, and 218.

The utilisation of gaseous chlorine obtained by the electrolysis of brine for the sterilisation of sewage effluents has been attempted both in America and also in this country, where Rideal's observations on the so-called oxy-chloride process furnish interesting facts.* The American experiments place the cost of such efficient treatment at about three shillings and sixpence per million gallons of effluent, allowing 5 parts of chlorine per million. Rideal's experiments at Guildford indicate that with a good effluent sterility can be ensured by the addition of about 5 parts per 100,000 of available chlorine. If removal of *B. coli* and *B. enteritidis sporogenes* only is aimed at, $\frac{1}{10}$th of the amount or even less is sufficient. The cost of this treatment is not stated, but the use of gaseous chlorine, manufactured at the sewage works by electrolytic methods on a large scale, might readily be reduced to an expenditure of not more than three shillings per million gallons of sewage effluent treated. Although further experiments upon a large scale are needed, still the process as thus outlined appears to us feasible and certainly desirable in cases where large volumes of sewage effluent have to be discharged into estuaries used as laying-beds for oysters and other shell-fish.

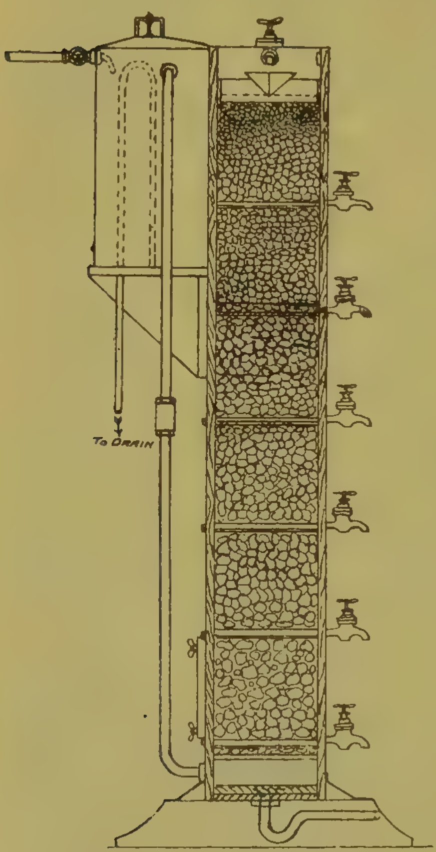


Fig. 92.—Scott-Moncrieff's Sewage Standardiser.

Doubtless, in the near future, further developments in the biological treatment of sewage will occur. These probably will assume the form of a greater and more exact control, not only of anaerobic, but also of aerobic action. In other words, we shall be able to establish standards for treating sewage in anaerobic beds or tanks for a definite time, and subsequently treating it in aerobic beds, containing particles of definite size, and the flow of both sewage and air being so controlled and regulated as to pass through the installation in definite quantities. A notable advance in this direction is the standardisation apparatus suggested by Scott-Moncrieff for determining the essential factors for success in the purification of sewage by passing through filter-beds. Before attempting to design bacterial installations, the values of the following factors should be known for any particular sewage :—(*a*) the volume to be discharged upon each foot of filter-bed per hour, or each acre for twenty-four hours ; (*b*) the period of time between each discharge ; (*c*) the air required for aeration per cubic foot or yard of filter ; (*d*) depth and nature of filter required for any given standard of purification. The apparatus (Fig. 92) consists of an air-tight box of standard dimensions, occupying a floor space of 4 feet by 3 feet, and some 8 feet in height. It contains a unit of filtering material, representing the actual working of a filter-bed, 6 feet in depth. By an automatic tipper, provision is made to determine accurately the volume and rate of delivery of sewage ; also, by means of a meter, of the amount of air necessary to secure any standard of

* Rideal : *Journal of the Royal Sanitary Institute*, vol. xxvi. No. 7, 1905. For further detailed information on this subject, the reader should consult *Sewage and its Purification*, by the same author, London, 1906.

nitrification. By means of taps, samples of effluent can be taken at every foot level from 1 to 6. A series of observations * made with this standardiser enables one to determine accurately the character of an effluent obtainable from a given sewage, under given conditions. We confess to being much impressed, not only with the scientific value of this apparatus, but also with its practical importance to all called upon to either advise as to, or actually construct, bacterial sewage installations. It is doubtful whether either the engineering or medical professions fully realise the value and importance of systematic work with this apparatus. The essential data for filter-beds and contact-beds are to be obtained only by either employing some such standardiser or by setting up a complete installation and gaining experience and knowledge of the facts by costly practical treatment of the sewage in bulk. The one method is logical, scientific, and, in most cases, likely to be the more economical; the other is purely empirical, and, not infrequently, as costly as it is unsatisfactory. The recent work, on these lines, done at Staines and Keighley † shows that the case for testing sewage in order to discover the conditions required for its purification before spending money in the dark has been proved, and we shall have good reason to complain if no action is taken by the proper authorities to place the whole subject upon a sounder footing.

It may be asked, legitimately, are there any established standards to which an effluent from a sewage installation should conform? No agreement on this point has yet been arrived at. The standard limit of impurity for effluents discharged into the Ship Canal have been laid down by the Mersey and Irwell Joint Committee as 1 grain per gallon oxygen absorbed at 80° F. in four hours, and 0·1 grain per gallon albuminoid ammonia. A further test for putrescibility, called the "incubator test" is also laid down. The oxygen absorbed in three minutes having been determined in the effluent, a bottle is completely filled with it, closed, and incubated at 80° F. for a week. If putrefaction has occurred, more oxygen will be required; while, if oxidation has taken place at the expense of the nitrates or dissolved air, slightly less oxygen will be required; or the absorption of oxygen may be unaltered. If nitrates exist in any large quantity in an effluent, it indicates that the organic matter has been well oxidised or mineralised, and such an effluent may not be without beneficial action in a stream, owing to oxygen being liberated from the nitrates by secondary bacterial action. Chlorine in sewage is unaffected by bacterial processes; its quantity in an effluent will show how far it is comparable with the original liquid. In forming an opinion on sewage effluents, our own practice has been to regard no effluent as satisfactory, if it (*a*) contain solids in suspension, (*b*) emits an odour, (*c*) consumes more than 1·5 parts of oxygen per 100,000 at 80° F. after four hours, (*d*) contains more than 0·150 parts of albuminoid ammonia per 100,000, (*e*) fails to withstand incubation at 80° F. for a week, and (*f*) presents a percentage purification, based on the mean of the oxygen and albuminoid figures, of not less than 90; the comparison being based on analyses of the original sewage and the finished effluent.

When moneys are borrowed for the establishment of sewage works, the Local Government Board in England has shown a tendency to impose severe conditions. Whether they are not too severe has been the subject of some controversy, and it is generally anticipated that the Report of the present

* Scott-Moncrieff: "The Standardisation of Sewage," *Journ. Roy. San. Inst.*, vol. xxiv. p. 160.

† Hopkinson: "Standardisation of Sewage Effluents," *The Sanitary Record*, April 5, 1906, p. 285.

Royal Commission may suggest some relaxation. The restrictions in vogue at present are as follows :—Sewage disposal works must be capable of dealing with six times the daily dry-weather flow of sewage. The bacteria-beds used must be able to overtake three times the dry-weather flow, the surplus being dealt with on prepared land. After six times the dry-weather flow has been dealt with, the storm water may be run through continuous filters to the outfall. If first and second contact-beds are used, the septic or other tank may not be required. If only single contact be given, a tank capable of containing one and a half times the dry-weather flow must be provided. In no case is the effluent from bacteria-beds permitted to pass directly into a stream, it must be treated first on land ; this, despite the use of the septic tank ; and the land required is at the rate of one acre to every 1000 persons. If contact-beds are worked automatically they may be filled thrice daily ; but if worked by hand, only twice. This means that the bacteria-beds need not be so large. If the sewers are laid on the separate system, the foregoing rules do not apply, and in different cases the Board may not insist upon every condition being complied with.

LAW RELATING TO REMOVAL OF EXCRETA FROM HOUSES AND HOUSE DRAINAGE.

In England and Wales.—The Public Health Act, 1875, sections 21 to 25, gives every Sanitary Authority power to enforce drainage of undrained houses, and in certain cases to close existing drains on condition of providing others. These drains must lead to the public sewer if there be any within 100 feet of the site of the house ; if not, to a covered cesspool in such position (not under a house) as the Sanitary Authority may direct. Failing compliance, the authority may carry out the work and recover in a summary manner the expenses incurred from the owner, or may by order declare the same to be " private improvement expenses." These private improvement expenses may be made payable by instalments with interest. They may, moreover, be levied on the occupier, whereas the expenses, if recovered summarily, will only be recoverable from the owner. It occasionally happens that, owing to delay in construction of sewers, houses have been supplied with cesspools and effectual drains leading thereto. In those cases, the Sanitary Authority are under no obligation to pay the costs of drains necessary for enabling the house to discharge its sewage into the new sewers. Where the sewer is in the same sanitary district as that in which the premises are situate, the owner or occupier, upon giving due notice and complying with the regulations of the authority as to how the communication is to be made, is entitled to carry drains into the public sewer. In places where Part III., Public Health Amendment Act, 1890, has been adopted, by section 18 of that Act, the owner or occupier has a right to require the Sanitary Authority to make the communication at his cost. Where the sewer is in another sanitary district, the communication must be made on such terms and conditions as may be agreed upon between the owner or occupier and authority to whom the sewer belongs.

Where any drain or cesspool is a nuisance, or injurious to health, the Sanitary Authority may take proceedings to remedy the matter either under section 41, Public Health Act, 1875, or under the provisions of the same Act relating to nuisances. All the foregoing provisions apply to existing houses and drains, without regard to the date of their construction in both urban and rural districts.

In urban districts, and in rural districts, or contributory places endowed with urban powers by section 276, Public Health Act, 1875, not only may *no* house be built or rebuilt after having been pulled down to or below the ground floor, or be occupied after having been built or so rebuilt until proper covered drains have been constructed and duly connected with either a sewer or cesspool, as above indicated, to the satisfaction of the Sanitary Authority (section 25, Act of 1875), but the authority may make bye-laws as to the mode in which connections between drains and sewers are to be made (*idem*, section 157). This 157th section of the 1875 Act is only of limited extent, as it provides that no bye-law made under it shall affect any building erected in any place which, on August 11, 1875, was included in an urban sanitary district before the Local Government Acts came into force in such place, or any building erected in any place which, on that date, was not included in any urban sanitary district before such place became constituted or included in an urban district, by virtue of any order of the Local Government Board, subject to this Act. Nor may any bye-law made under the section apply to buildings belonging to any railway company, and used for the purposes of such railway under any Act of Parliament. In places where Part III., Public Health Amendment Act, 1890, has been adopted, section 23 of this same Act has extended the operation of this 157th section of the 1875 Act to buildings erected before the time mentioned, and to rural sanitary districts. Rural Sanitary Authorities can therefore now, by adopting this part of the 1890 Act, obtain these very important powers throughout their districts without the intervention of any order of the Local Government Board.

The law relating to privies, water-closets, excrement and refuse disposal, resembles that relating to house drainage, inasmuch as it is contained partly in statutory enactments applicable to both urban and rural sanitary districts, and partly in bye-laws applicable only to urban districts and to those rural sanitary districts or contributory places to which they have been specially applied by order of the Local Government Board. The general statutory enactments in regard to these matters of excrement and refuse disposal are contained in the Public Health Act, 1875, sections 36 to 45, and practically amount to the following :—It is unlawful to erect any house without a sufficient water-closet, earth-closet or privy, and an ashpit with proper doors and coverings ; and the same must be provided for any existing house on the order of the Sanitary Authority, who may require a separate closet for each house (sections 35, 36, and 37). The Sanitary Authority may order sanitary conveniences in factories where persons of both sexes are employed (section 38), while the Coal Mines Regulation Act, 1887, section 74, makes the same provision applicable to parts of mines above ground in which women and girls are employed. Every Sanitary Authority must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (section 40), while urban Sanitary Authorities may provide public urinals, closets, or receptacles for refuse (sections 39 to 45). On the written complaint of any person that any drain, closet, ashpit, or cesspool is a nuisance, the Sanitary Authority may, by writing, empower their surveyor or inspector, after giving twenty-four hours' notice, to enter the premises and open the ground : if any defect is found, the Sanitary Authority must serve notice upon the owner or occupier to do the necessary work, but if there is no defect, the Sanitary Authority must close the ground and make good any damage.

The Local Government Board have issued a series of Model Bye-laws relating to the various matters for which bye-laws may be made by a

Sanitary Authority under the foregoing provisions. Their general provisions are sufficiently indicated in the following summary :—

Drainage.—Damp sites must be drained by earthenware field-pipes properly laid to a suitable outfall, but not directly communicating with any sewer or cesspool or drain containing sewage. Rain-pipes must be provided to carry away all water falling on the roof without causing dampness of the walls or foundations. The level of the lowest storey must be such as to allow of the construction of a drain sufficient for the drainage of the building communicating with a sewer at a point above the centre of the sewer. All drains for sewage must be made of impervious pipes 4 inches or more in internal diameter, laid with a proper fall in a bed of concrete, and with water-tight joints. Every drain inlet not intended for ventilation must be trapped. No drain conveying sewage must pass under a building unless no other mode of construction is practicable ; in that case it must be laid in a direct line for the whole distance beneath the house, and must be embedded in and covered with concrete 6 inches thick all round, and must be laid at a depth below the surface at least equal to its diameter, and lastly, must be ventilated at each end of the portion beneath the building. The main drain must be trapped at a point within the curtilage, but as distant as practicable from the building. Branch drains must join other drains obliquely in the direction of the flow.

There must be at least two untrapped ventilating openings into the drains, according to one of the following alternative arrangements :—(1) One opening consists of a shaft or disconnecting chamber opening at or near the ground level, and situated as close as possible to the trap specified above, but on the house side of it ; the other opening is a pipe or shaft carried from a point as far distant as possible from the said trap, that is, as near as possible to the head of the drain, vertically upwards in such manner and to such height (in no case less than 10 feet) as to prevent any escape of foul air into any building ; but (2) if more convenient, the relative positions of these openings may be reversed, the shaft being placed near the trap, and the opening at the ground level at the head of the drain. The ground level opening must have a grating, with apertures equal in total area to the sectional area of the drain. The pipe or shaft at the other end of the drain (whether used as a soil-pipe or not) is required to have a sectional area equal to that of a drain, and in no case to be less than 4 inches ; all bends and angles are to be avoided as far as practicable.

No drain inlet is permitted within a building except the inlet necessary for a water-closet. Every soil-pipe must be at least 4 inches in diameter, must be placed outside the building, and must be continued upwards in full diameter, without bends or angles, to such a height and such a point as to afford a safe outlet for sewer air. This height and point will usually be above the highest part of the roof of the building to which the soil-pipe it attached, and, where practicable, not less than 3 feet above any window within 20 feet, measured in a straight line from the open end of such soil-pipe. There must be no trap between the soil-pipe and the drain to which it leads, nor in any part of the soil-pipe except such as may be necessary in the construction of the water-closet. The waste-pipe from a slop sink must conform to the same requirements as a soil-pipe. The waste-pipes from any other sink, bath, or lavatory, the overflow pipe from any cistern and from any " safe " under a bath or water-closet, and every pipe for conveying waste water, must be taken through an external wall, and must discharge in the open air over a channel leading to a trapped gully grating at least 18 inches distant.

Water-closets must have a window opening directly into the external air, and measuring 2 feet by 1 foot clear of the frame ; and, in addition to the window, adequate means of constant ventilation by air-bricks, air-shafts, &c. Such closets, if within the building, must adjoin an external wall. The water must be supplied to a water-closet by means of a special cistern. The apparatus must be suitable for effectual flushing and cleansing of the basin ; the basin must be made of non-absorbent material, and of such shape and capacity as to receive and contain a sufficient quantity of water, and to allow all filth to fall free of the sides directly into the water. " Containers " and " D traps " are forbidden.

Earth-closets are subject to the same conditions as water-closets, so far as regards position, lighting, and ventilation. Proper arrangements must be made for the supply of dry earth, and its effectual and frequent application to the excreta ; also for convenience of scavenging, and for exclusion of rainfall and drainage. The receptacle for excreta, whether fixed or movable, must be so constructed as to prevent absorption or escape of the contents, and to exclude rainfall and drainage ; if fixed, its capacity must not be greater than may suffice for three months, nor in any case greater than 40 cubic feet, and it must in every part be 3 inches above the ground. In the case of earth-closets placed inside houses, the maximum limit of size may with advantage be reduced to 2 cubic feet.

Privies must not be erected within 6 feet of a dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, nor otherwise in such a position as to entail danger of the pollution of such water. Privies must be built so as to admit of convenient scavenging without carrying the contents through any dwelling, public building, or place of business. There must be an opening for ventilation at the top ; the floor must be paved, and raised 6 inches above ground in all parts, with a fall of half an inch towards the door. The receptacle may be fixed or movable. If movable, as in pail-closets, the floor of the area beneath the seat must be flagged or asphalted, and raised 3 inches above the ground level, and all the sides

of the said area must be made of flag, slate, or brick, at least 9 inches thick, and rendered in cement. If the receptacle is fixed, it must be in every part 3 inches above the ground level, and its capacity not exceeding 8 cubic feet, presuming that the scavenging will be done weekly. Suitable means or apparatus must be provided in connection with the privy for the application of ashes, dust, or dry refuse to the filth deposited; and the receptacle must be so constructed that the contents may not at any time be exposed to rainfall, or to the drainage of any waste water or liquid refuse from any adjoining premises, while at the same time conveniently accessible for scavenging. The materials and construction must be such as to prevent any absorption by any part of it of any filth deposited therein, or any escape by leakage or otherwise of its contents. It must in no way be connected with a drain.

Cesspools must not be constructed within 50 feet of any dwelling, public building, or place of business, nor within 100 feet of a water likely to be used for drinking or domestic purposes, or for manufacturing drinks, or otherwise in such a position as to entail danger of pollution of such water. Cesspools must be so constructed and placed as to conveniently admit of scavenging and cleansing without carrying the contents through any dwelling, public building, or place of business. They must not be connected with any sewer. They must be covered by an arch, or otherwise, and adequately ventilated. They must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 inches of clay.

In London.—In regard to house drainage, water-closets, privies, cesspools, ashpits, the removal and disposal of refuse, the receptacles for dung, and the proper accessories thereof in connection with new buildings or old, by section 39 (1) of the Public Health (London) Act, 1891, the County Council are empowered to make bye-laws, which it is the duty of every Sanitary Authority in London to enforce and observe. Bye-laws made by the County Council under the Act do not, however, extend to the city. These bye-laws and any others made by the County Council, under this Act, are subject to the provisions of sections 182 to 185 of the Public Health Act, 1875, as already explained in connection with bye-laws made by any Sanitary Authority in England and Wales; in their main provisions the bye-laws made by the County Council accord closely with those given above as models by the Local Government Board. Earth-closets, privies, and receptacles for dung must, by the London County Council bye-laws, be emptied and cleansed weekly; while cesspools must be similarly treated every three months.

The obligations and powers of a Sanitary Authority in London in relation to house drainage and the removal of refuse are very similar to those of a Sanitary Authority in other parts of the country. A new house *must* have "one or more water-closets, as circumstances may require," with proper water-supply, trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the Sanitary Authority (section 37). A privy or earth-closet may only be substituted if the available sewerage and water-supply is insufficient for a water-closet. Any person who may think himself aggrieved by any notice or act of the Sanitary Authority may appeal to the County Council, whose decision is final. These appeals are governed by section 126. Penalties are prescribed for (*a*) constructing or re-constructing water-closets, &c., not in accordance with this Act or any bye-laws, or in defiance of notice or prohibition; (*b*) for discontinuing any such water-supply without lawful authority; (*c*) illegally or wilfully injuring or constructing a drain or water-closet so as to create a nuisance or danger to health (section 41).

In Scotland.—When no house drain exists, an owner may, under the Public Health (Scotland) Act, 1897, section 120, be compelled to make one, and in the absence of a public sewer within 100 yards to provide a cesspool; but there is no provision for compelling or ensuring that new houses are properly drained. This defect in the Act is practically minimised by the elasticity of the term nuisance under the same Act, which includes any insufficiency of drainage and water-closet accommodation. In the towns,

subject to the provision of the Burgh Police Act, 1892, power is given to the burghal authorities, which do not materially differ from the English provisions (sections 238 to 245), except that what are contained in detailed regulations in the Scottish Acts are, in England, left to be prescribed in the form of bye-laws.

In Ireland, a Sanitary Authority is empowered to enforce the drainage of undrained houses, but it is not compulsory on them to do so, as in England. The Sanitary Authority may also, by the Irish Public Health Act, 1878, require drains and cesspools to be ventilated as may appear necessary (section 25 *et seq.*). As to drainage in the case of newly built or rebuilt houses, a rural Sanitary Authority cannot enforce it; but it can make bye-laws with respect to the drainage of buildings, a provision which to some extent covers the same ground. This power of making building bye-laws is, in Ireland, given to rural as well as to urban Sanitary Authorities, without requiring, as in England, an order by the Local Government Board (section 41). The Irish Board has not issued any special model bye-laws, as those of the English Local Government Board are fully applicable to Ireland.

The general provisions in the Irish Act (section 44 *et seq.*) relating to sanitary conveniences, &c., are almost the same as those in the English Act of 1875.

LAW RELATING TO SEWERAGE AND DISPOSAL OF SEWAGE.

In England and Wales.—By the Public Health Act, 1875, section 13, it is enacted that all sewers except certain private sewers are vested in the Sanitary Authority of the district. The exceptions mentioned in the section are:—(1) Sewers made by a person or persons for his or their profit. (2) Sewers made and used for draining or improving land under any local or private Act, or for irrigation. (3) Sewers under any Commmissioners of Sewers appointed by the Crown. The Sanitary Authority may purchase (section 14) or construct (section 15) sewers. They must provide such sewers as are necessary for effectually draining their district, having, by section 16, powers of taking them through, across, or under lands and streets. Section 308 provides for compensation for damage, to be ascertained by arbitration. The sewers must be so constructed, covered, ventilated, and kept as not to be a nuisance or injurious to health, and must be properly cleansed (section 19). The performance of these duties by a Sanitary Authority can be enforced on complaint by individuals (section 299), while further powers, in this respect, are given by sections 16 and 19 of the Local Government Act, 1894, to County Councils, on complaint by a Parish Council of a defaulting rural Sanitary Authority.

Under section 7, Rivers Pollution Prevention Act, 1876, every Sanitary Authority must give facilities for factories to drain into sewers, but provision is given for the protection of sewers from injurious matters, such as anything which may impede the flow of their contents, any chemical refuse, waste steam, or water or liquid heated above 110° F., by sections 16 and 17, Public Health Acts Amendment Act, 1890. The restrictions imposed by sections 32, 33, and 34 of the Public Health Act, 1875, on the execution of sewerage works by a Sanitary Authority outside its own district, involve the giving of a public notice, and in case of objection, the work not to be commenced without sanction of the Local Government Board, who may appoint an inspector to make inquiry and report.

For the protection of the sewers of an urban Sanitary Authority, section 26, Public Health Act, 1875, provides a penalty for unauthorised buildings over them; and sections 150 and 151 give power to the Sanitary Authority to compel the sewering of private streets, subject to any bye-laws the authority can get confirmed by the Local Government Board. Powers are given by section 27 of the same Act for the treatment and disposal of sewage, but section 17 expressly insists that such disposal of sewage must not be into streams, unless purified before discharge; this latter section, however, needs to be read in connection with the Rivers Pollution Prevention Acts, 1876 and 1893, which give a certain amount of protection to Sanitary Authorities in respect of the pollution of streams and rivers by sewage channels used, constructed, or in process of construction at date of passing of the Act of 1876. Sections 28, 29, and 30 of the Public Health Act, 1875, further give powers to the Sanitary Authority to deal with land appropriated to sewage purposes, to contribute to works executed by others for the disposal of the sewage and to agree for communication of sewers with sewers of adjoining districts.

The incidence of the charge of sewerage and other public sanitary works in urban districts is usually made by a general district or borough rate. In rural districts, the incidence of charge of expense of sewerage and other sanitary works is not made on the entire district, but constitutes a separate charge on the parishes or parts of parishes for which the works have been carried out, and the areas liable to contribute are termed "contributory places" (section 229). There are four kinds of contributory places:—(1) A rural Sanitary Authority may, subject to approval by the Local Government Board, constitute any portion of its area a "special drainage district" for the purpose of charging thereon exclusively the expenses of sanitary works, the cost of which is not spread over the entire district, and thereupon such area becomes a "contributory place." (2) Where no part of a parish is situate in a special drainage district, or in an urban sanitary district, the entire parish is a contributory place. (3) Where no part of a parish is in an urban sanitary district, but part of it is in a special drainage district, the part not in a special drainage district is a contributory place. (4) Where part of a parish is in an urban sanitary district, and part in a rural sanitary district, so much of it as is not in an urban district or special drainage district is a contributory place (section 229).

In London.—The County Council, as the successors of the Metropolitan Board of Works, are the Local Authority for the purposes of the main sewerage and disposal of the sewage of London, while the Borough Councils are the Local Authorities for the purposes of the sewerage and drainage other than the main sewerage. The powers of the late Metropolitan Board of Works, and consequently of their successors, the County Council, as regards main sewerage are derived from the Metropolis Management Act, 1855, taken in conjunction with a similar Act of 1862, and the Metropolitan Main Drainage Act, 1858.

While the main sewers are to be constructed and kept so as not to be a nuisance, the County Council have power to declare sewers to be main sewers, and to take jurisdiction over sewerage and drainage matters belonging to the boroughs, also to control these bodies in the construction of sewers, &c., by means of bye-laws. The general powers of the County Council in respect of sewerage and sewage disposal are very similar to those of the Sanitary Authorities in the provinces under the Public Health Act, 1875. As relates to procedures for the prevention of floods, the powers of the County Council, by inheritance from the Metropolitan Board of Works, are derived from the

Metropolitan Management (Thames River Prevention of Floods) Amendment Act, 1879.

By the Metropolis Management Act, 1855, section 68, all sewers. other than those now vested in the County Council and the City Corporation, are vested in the Borough Councils, who, from time to time, must repair, maintain, alter, or extend as may be necessary; but no new sewers can be made without the approval of the County Council. The powers given by the above provisions are extended in certain cases to areas outside the metropolis by section 58 of the Metropolis Management Act, 1862. The Act of 1855 (sections 73 to 75) further provides for the ventilation, trapping, cleansing, inspection, and proper connection of drains with sewers on the part of the Sanitary Authorities; while section 202 of the same Act gives the Local Authorities power to make bye-laws as to drains. For the purposes of their sewers, and for other purposes of the Metropolis Management Acts, every District Council has the same power as the County Council to purchase lands. These purchase powers, however, are not compulsory (sections 151, 152).

In Scotland.—While the Scottish Acts do not draw any formal distinction between drains and sewers, the duties of Local Authorities in regard to their provision and maintenance do not materially differ from those of the English Sanitary Authorities; the powers being derived from the provisions of the Public Health (Scotland) Act, 1897, the Burgh Police (Scotland) Act, 1892, and the Local Government (Scotland) Act, 1889. Though the pollution of a stream by sewage is an offence as a nuisance under the common law of Scotland, it is also so under section 21 of the Rivers Pollution Prevention Act, 1876 and 1893, which applies to Scotland, with the substitution of the Local Government Board for Scotland as central authority. A County Council may enforce this Act as if it were a Sanitary Authority within its meaning.

In Ireland.—The provisions of the Irish Public Health Act, 1878, in respect of sewerage and sewage disposal are identical with those of the English Act of 1875. The Rivers Pollution Prevention Acts, 1876 and 1893, extend also to Ireland, but in their practical application there is some doubt whether the definition of Sanitary Authority contained in the Act of 1876 can be held to include a Sanitary Authority constituted by the Irish Public Health Act of 1878. In respect of the incidence of taxation to meet loan charges for sanitary works, it is noticeable that the definition of a contributory place in the Irish Act is different from that contained in the English Act. By section 232 of the Public Health Act (Ireland), 1878, a contributory place may be (1) the dispensary district; (2) the electoral division; (3) the town-land; (3) such portion of the town-land or town-lands as may be determined by the Local Government Board of Ireland.

Another distinction between the two Acts is that there are no "special drainage districts" in Ireland, their place being taken by the "area of charge," consisting of a contributory place or a number of contributory places benefiting by proposed sanitary improvements. An area of charge differs from a special drainage district, inasmuch as it may be, and usually is, fixed for one particular work, and the same area need not be adopted for the expenses of another sanitary work for the same place.

CHAPTER XIII

DISPOSAL OF THE DEAD

When we remember that some fifteen hundred persons die daily in England and Wales, the question of how to dispose of this enormous number of dead, in such manner as to avoid danger to the living, becomes a sanitary problem of no little importance ; particularly as many of these dead persons have died of an infectious disease. In the past, undoubted errors were committed by overcrowding of graveyards, and there can be no question as to the injurious effects of these overcrowded burial-places upon the health of the immediately surrounding population, but there is no evidence of evil resulting from the conditions enforced in modern well-regulated cemeteries.

In all burial-grounds, the object aimed at is the rapid resolution and complete oxidation or absorption by the soil of the bodies deposited therein. For this reason, the soil should be porous, light, and either naturally or artificially drained to a depth of eight feet. Loam or sand is probably the best soil ; clay is difficult to drain and either retains the products of decomposition or allows them to escape through fissures. The location of cemeteries is often a matter of difficulty, but the principles to be borne in mind are :—(*a*) place them well beyond the limits of present or probable future dense building areas; (*b*) allow a peripheral margin of twenty-five feet in width for trees, shrubs and walks ; (*c*) avoid elevated ground, whence the natural drainage may find its way to dwellings or water-supplies at a lower level. The ordinary grave space being 9 feet by 4, it is estimated usually that an acre of ground is a minimum allowance as a burial-ground for 4000 people for fourteen years. There can be little doubt but that our present practice of deep burial is inconsistent with the efficient and rapid resolution of the bodies we consign to the earth ; as, if corpses are covered by a foot of suitable earth, the perishable parts disappear inoffensively within a year ; and speaking broadly, it may be said that for each foot of depth below the soil surface at least a year is required for complete decomposition and resolution of the soft parts. The objects of earth-burial are further frustrated by the use of brick graves, vaults, and heavy oak or metallic coffins ; all these are objectionable and illogical, and futile attempts to prevent decomposition. It is to be hoped that these customs will gradually give way to the more rational employment of perishable coffins of wicker, light wood or *papier-maché*.

LAW RELATING TO MORTUARIES AND BURIAL-GROUNDS.

In England and Wales.—Under the Public Health Act, 1875, every Sanitary Authority *may*, and if required by the Local Government Board *must*, provide a mortuary, and may make bye-laws for its management and the charges for its use. They may also provide for the decent

interment, at charges to be fixed by such bye-laws, of any dead body which may be received into a mortuary (section 141). A justice may, on a certificate signed by a medical practitioner, order to be removed to a mortuary, at the cost of the Sanitary Authority, the body of any one who has died of any infectious disease, and which is retained in a room in which persons live or sleep, or any dead body which is in such a state as to endanger the health of the inmates of the house or room in which it is retained. He may direct the same to be buried within a specified time. If the friends fail to comply, it is the duty of the Relieving Officer to bury, and the expenses may be recovered from the proper person (section 142).

The Local Government Board have issued a series of Model Bye-laws with respect to the management of a mortuary; the only provisions of sanitary importance suggested in them are the following :—

A body deposited in the mortuary shall be removed therefrom for interment within . . . days after death; but if the deceased has died of an infectious disease, the body shall be removed for interment within . . . days after death.

The Board have also made the following suggestions in regard to the construction and management of mortuaries :—

The buildings should be isolated and unobtrusive, but substantial, structures of brick or stone. Every chamber for the reception of corpses should be on the ground floor. In addition to such chamber there should be a waiting-room, a caretaker's house, and a shed or outhouse. Every mortuary chamber should be lofty, and there should be a ceiling or a double roof, with an intervening space of 8 inches, for the sake of coolness. The area should be sufficient to allow freedom of movement between the slabs. The windows should be on the north side, if practicable; if otherwise, they should have external louvre blinds. Louvres, or air-gratings, under the eaves will be the best means of ventilation. The pavement must be even and close, and a cement floor is preferable. The slabs should be of slate, and $2\frac{1}{2}$ feet to 3 feet from the floor. Water should be laid on within the chamber. The walls and ceiling should be whitewashed, and the outside of the roof also whitened. There should be at least two chambers, one of which may be reserved for bodies of persons who have died of infectious disease.

There should be a resident caretaker, and bodies should be received at any hour of the day or night.

In addition to mortuaries, Sanitary Authorities may provide and maintain proper places, otherwise than at a workhouse or at a mortuary, for the carrying out of *post-mortem* examinations (section 143).

The powers and duties of Sanitary Authorities as regards mortuaries are extended to cemeteries by the Public Health (Interments) Act, 1879, section 2, whereby both urban and rural authorities are enabled to provide cemeteries for their districts, and must do so if required by the Local Government Board. The cemetery need not be within the district of the Local Authority. In a Memorandum issued in August 1879, the Board point out that it is incumbent upon the Sanitary Authority to take action :—

1. Where, in any burial-ground which remains in use there is not proper space for burial, and no other suitable burial-ground has been provided.

2. Where the continuance in use of any burial-ground (notwithstanding there may be such space) is by reason of its situation in relation to the water-supply of the locality, or by reason of any circumstances whatsoever, injurious to the public health.

3. Where, for the protection of the public health, it is expedient to discontinue burials in a particular town, village, or place, or within certain limits.

The necessity may also arise from unsuitability of the site or of the subsoil, or from inconvenience of access from populous parts of the district.

If it is desirable, upon the above or other grounds, to close any existing burial-place, a representation must be made to the Home Secretary for

the purpose of obtaining an Order in Council to that effect, under the provisions of the Burial Act of 1853.

Assuming that a cemetery is required in any locality, it may be provided either by the Sanitary Authority under the Interments Act, 1879, or by the formation of a Burial Board under the Burial Acts. As to which procedure should be adopted will be mainly decided by the circumstances of the district. The chief arguments in favour of the Sanitary Authority are that it has at its disposal an efficient staff of officers and advisers, besides which it can obtain compulsory powers of purchase of land by means of a Provisional Order, which a Burial Board cannot obtain. On the other hand, the area for which the cemetery is required may not be wholly comprised within the sanitary district, nor be conterminous with any contributory place therein.

Section 10 of the Public Health (Interments) Act, 1879, forbids the construction of a cemetery within 200 yards of any dwelling without the consent of the owner and occupier. There is no restriction if such consent is obtained, nor any prohibition of future building nearer to the cemetery. In the case of cemeteries constructed under the Burial Acts, this distance is reduced to 100 yards.

The following Regulations for Burial-grounds provided under the Burial Acts were issued by the Home Secretary in 1863, and are now still in force :—

(1) The burial-ground shall be effectually fenced, and, if necessary, underdrained to such a depth as will prevent water remaining in any grave or vault.

(2) The area to be used for graves shall be divided into grave spaces, to be designated by convenient marks, so that the position of each may be readily determined, and a corresponding plan kept on which each grave shall be shown.

(3) The grave spaces for the burial of persons above twelve years of age shall be at least 9 feet by 4 feet, and those for the burial of children under twelve years of age 6 feet by 3 feet, or, if preferred, half the measurement of the adult grave space—namely, 4½ feet by 4 feet.

(4) A register of graves shall be kept, in which the name and date of burial in each shall be duly registered.

(5) No body shall be buried in any vault or walled grave unless the coffin be separately entombed in an air-tight manner ; that is, by properly cemented stone or brickwork, which shall never be disturbed.

(6) One body only shall be buried in a grave at one time, unless the bodies are those of members of the same family.

(7) No unwalled grave shall be reopened within fourteen years after the burial of a person above twelve years of age, or within eight years after the burial of a child under twelve years of age, unless to bury another member of the same family, in which case a layer of earth not less than a foot thick shall be left undisturbed above the previously buried coffin ; but if on reopening any grave the soil is found to be offensive, such soil shall not be disturbed, and in no case shall human remains be removed from the grave.

(8) No coffin shall be buried in any unwalled grave within 4 feet of the level of the ground, unless it contains the body of a child under twelve years of age, when it shall not be less than 3 feet below that level.

The application to cemeteries of section 141 of the Public Health Act, 1875, enables Sanitary Authorities to make bye-laws for their management and charges for use. The following represents the essential provisions of the Model Bye-laws issued in respect of this matter by the Local Government Board.

(*a*) *Definitions.*—A " grave " is defined as a burial-place formed in the ground by excavation, and without any internal wall of brickwork or stonework, or any other artificial lining. A " vault " is an underground burial-place of any other construction. (*b*) *Vaults.*—Every vault shall be enclosed with walls of brick or stone, solidly put together with good mortar or cement. (*c*) *Common graves.* Not more than one body shall be buried at any one time in a grave in respect of which no exclusive right of burial has been granted. (Exception is made in the case of two or more members of the same family.) Such a grave shall not be re-opened for the purpose of a further burial within eight years after the burial of a person aged less than twelve years, nor within fourteen years after the burial of a person aged more than twelve years. (Exception is made in the case of members of the same

family.) (*d*) *Minimum covering of earth.*—No part of a coffin shall be buried at a less depth than 3 feet below the ground adjoining the grave, if it contains the body of a person aged less than twelve years; nor at a less depth than 4 feet if the age of the deceased was over twelve years. A layer of earth, not less than 1 foot in thickness, shall be interposed between every coffin and the coffin nearest to it. (*e*) *Closure of vaults.*—A coffin buried in a vault shall, within . . . hours after burial, be wholly and permanently embedded in and covered with good cement concrete, not less in any part than . . . inches in thickness; or wholly and permanently enclosed in a separate cell, constructed of slate or flag, not less than 2 inches thick, and jointed in cement, or of brick in cement, and in such manner as to prevent, as far as practicable, the escape of noxious gas.

Interments underneath or within the walls of any church built after 1848 are forbidden by the Public Health Act, 1848, section 33, incorporated in the Act of 1875. No buildings must be erected upon any disused burial-ground, except for the purpose of enlarging a place of worship (Disused Burial-grounds Act, 1884).

In London, under the Public Health Act, 1891, every Sanitary Authority must provide mortuaries and places for *post-mortem* examinations when so required by the County Council (sections 88 and 90). Subject to the consent of the Local Government Board, the Local Authorities have power to borrow money for these purposes (section 105). The Corporation are the Burial Board for the City of London. The general law as to cemeteries is the same in the Metropolis as in the provinces.

In Scotland, a Local Authority may provide a mortuary, but the Local Government Board have no power to require them to do so (Public Health Act, 1897, sections 68 and 71). A parochial Board has a similar power under section 20, Burial-grounds (Scotland) Act, 1855. Though the Local Authorities cannot provide burial-grounds, they can act in regard to any of them which are so situated or crowded with bodies, or otherwise so conducted as to be offensive or injurious to health, as a statutory nuisance. So far as relates to disused burial-grounds, there are no Scottish provisions at all corresponding to the English Statutes.

In Ireland.—The provisions of the Irish Public Health Act, 1878, section 157, relating to mortuaries, are similar to those in the English Act of 1875. The Public Health (Interments) Act, 1879, does not apply to Ireland, but, on representation being made, the Local Government Board may restrain the opening of new burial-grounds, and order discontinuance of burials in specified places (Public Health Act, 1879, section 162). Under section 160 of this same Act, Sanitary Authorities, except in towns having Commissioners under local Acts, are the Burial Board of the district. In the towns just excepted, the guardians of the poor are the Burial Board. Whenever any burial-ground has been closed by order, the Burial Board of the district have power to provide a suitable cemetery, with powers to purchase land compulsorily, appropriate, lay out, and otherwise manage as they may deem necessary, subject at all times, however, to any Regulations which the Local Government Board of Ireland may make in respect of them (sections 172 to 234).

CREMATION.

The extension of the modern practice of cremation will simplify many of the difficulties associated with ordinary earth-burial, as in a modern crematorium a body of average weight is reduced to about 3 lb. of inorganic ash within two hours. The usual fuel is coal and coke, with a ventilating shaft having a pilot fire at its base. The chief objections to cremation are that the soil is deprived of the organic matter that would other-

wise be returned to it, and that the impossibility of exhumation increases the facilities for concealing homicide. We question whether the first objection has any great weight, as little attempt is made to utilise burial-grounds by cultivation. The second objection is, however, more serious and cannot be regarded as satisfactorily met by the proposal for minute and detailed autopsy in every case; in our opinion, such a procedure is quite impracticable; even if it were feasible, the discovery of organic disease would not exclude necessarily the possibility of foul play. The discovery of a few poisons, such as copper, might be detected in the ashes, but all organic and volatile mineral poisons would be dissipated by cremation. It is true that exhumation is rarely required, but the possibility of it undoubtedly checks crime.

The Cremation Act, 1902, empowers Burial Authorities (Burial Boards or other Local Authorities maintaining cemeteries) in England, Wales, and Scotland to provide and maintain crematoria. The plans and site must be approved by the Local Government Board, and the completion must be notified to the Home Secretary before any cremation takes place. No crematorium may be built within 50 yards of any public highway, within 200 yards of a dwelling-house (except by consent of owner), or within the consecrated part of a burial-ground.

The Home Office Regulations, dated March 31, 1903, and made under section 7 of the Cremation Act, 1902, impose conditions as to maintenance, inspection (by Home Office and Local Government Board), disposal of ashes, and the further points stated below. Cremation is not allowed if the deceased has left written directions to the contrary, or if the body has not been identified. There must be (*a*) medical certificates as to the cause of death from two registered practitioners (one being the medical attendant and the other a practitioner of at least five years standing, who (1) is specially appointed by the authority for the purpose; or (2) is Medical Officer of Health, certifying surgeon under the Factory Act, or medical referee under the Workmen's Compensation Act; or (3) is physician or surgeon to a public general hospital with at least 50 beds); or (*b*) a certificate given after *post-mortem* examination by a skilled pathologist; or (*c*) a certificate given by a coroner after inquest. In certain circumstances (*b*) and (*c*) become compulsory.

A medical referee must be appointed by the authority, and a deputy to act for him in his absence or in cases where he is the medical attendant. His certificate that all the conditions have been fulfilled is necessary before any cremation can take place, but certain relaxation can be allowed by him in exceptional cases (persons dying of plague, yellow fever, or cholera, on ship or in an isolation hospital; still-born children; bodies exhumed after burial for more than a year). Other modifications can be made temporarily by order of the Home Secretary on application of the Sanitary Authority, during an epidemic or for other sufficient reason.

CHAPTER XIV

OFFENSIVE TRADES

Certain businesses frequently come under the notice of the Medical Officer of Health as giving rise either to nuisance, or as proving injurious to the health of the community. While the actual number of these so-called offensive trades is considerable, and the facts as to their being a frequent source of nuisance are beyond dispute, it must be admitted that the evidence regarding their prejudicial influence upon the health of either workmen engaged in them or upon surrounding populations is imperfect. Be this as it may, their possible powers for evil are so great that their supervision constitutes one of the most important duties of the Sanitary Authority; and a knowledge of the chief sources of nuisance likely to arise in each business or group of businesses is imperative upon the Sanitary Officer. Ballard, to whose exhaustive report on effluvium nuisances, made to the Local Government Board in 1876–7, we are mainly indebted for information on this subject, classifies the offensive trades as follows :—

(1) The keeping of animals.

(2) The slaughtering of animals.

(3) Other branches of industry, in which animal matters or substances of animal origin are principally dealt with.

(4) Branches of industry in which vegetable matters are principally dealt with.

(5) Branches of industry in which mineral substances are principally dealt with.

(6) Branches of industry of mixed origin, in which mineral, vegetable, and animal substances are dealt with.

Keeping of Animals.—Offence most usually occurs from the keeping of either cows, horses, or pigs, and the question of nuisance in connection therewith arises mainly in towns. The sources of nuisance from the keeping of these animals are :—(*a*) the storing of grains or other food-stuffs; (*b*) emanations from their dung; (*c*) fouling of the air in or around sheds, stables, or styes; (*d*) soakage of urine into the ground from imperfect paving.

Few cow-sheds are adequately ventilated, and when we remember that the cow passes daily large quantities of semi-liquid manure, much urine and flatus, the difficulties in the way of keeping cow-sheds sweet in smell are enormous. In addition to this, grains are constantly stored in towns as food for cows. These grains are in a wet state, and unless freed from liquid, rapidly generate a sour odour from acetous fermentation. The only remedy for these defects is to provide large airy cow-sheds, with impermeable floors, an ample supply of water, racks and partitions made of iron, and walls lined with glazed tiles. The general regulations in force as to cow-keeping have been referred to in chapter v., when considering the legislation relating to milk-supplies.

The keeping of stables and mews in proper order presents daily difficulties to the Sanitary Authorities of towns, especially when the floor above

is used as a habitation. Similar objections are likely to arise in connection with stables as with cow-sheds. The chief source of nuisance is the storage of dung in heaps where it is liable to ferment, and when disturbed to give off watery vapour highly charged with ammonia. Horse-dung should be either removed daily, or stored in open iron cages near the stable door. Ammoniacal emanations may be controlled by damping the manure with dilute sulphuric acid, which in no way will decrease its commercial value as a fertilising agent.

As regards the keeping of pigs, the Public Health Act, 1875, section 47, states that pigs must not be kept in towns so as to be a nuisance, and the Public Health (London) Act, 1891, section 17, prohibits pigs being kept in the metropolis so as to be either a nuisance or within 40 feet of a street. Pig-styes, in all places, should be situated at a considerable distance from dwelling-houses; they should have impermeable floors, with a proper slope, and be provided with a gutter communicating with the drain by a trapped opening. The "wash" and other materials evolving effluvium should be kept in air-tight vessels.

The keeping of poultry in large towns is often a source of nuisance, especially among the poor, who frequently endeavour to keep fowls either in the cellars of their houses or in very small back-yards. The only effectual remedy is to forbid the keeping of poultry in towns altogether.

Slaughtering of Animals.—While the general state of the law in regard to slaughter-houses and knackeries is considered in the later part of this chapter, it is necessary in this place to mention briefly those features of these businesses which are liable to be sources of offence or nuisance. Places for the slaughtering of animals are either private or public (abattoirs). In this country the greater number are private establishments, but it is hoped that the time is not far distant when private slaughter-houses will be abolished, as experience indicates that neither the public health nor the sale of diseased flesh can be efficiently safeguarded except by a system of public abattoirs.

The chief difficulties in connection with slaughter-houses and knackeries arise from the filthy way in which the live animals are kept before slaughter, or owing to putrid carcasses and other material being allowed to remain on the premises, or from garbage and refuse. "The place where cattle are kept and fed for several days before killing is technically called a 'lair,' but where they are temporarily detained before slaughter is called a 'pound'; but in small businesses the one shed or place serves for both lair and pound."

If strictly defined, a knacker is properly a horse-slaughterer, but he also kills old and diseased animals other than horses, and commonly receives carcasses of animals which have died of disease or violence as well. In addition to the sources of nuisance common to slaughter-houses, the chief causes of offence in knackeries arise, not from the slaughtering, but from subsidiary trades—bone-boiling, flesh-boiling (for fat extraction or cats' meat), manure-making, &c. &c.—which are usually carried on at knackeries in order not to waste the materials.

The ordinary slaughter-man or butcher disposes of the "offal" or *débris* readily. The blood is either used for making "black puddings," when mixed with fat and condiments, or it is sold for pigs' food, or it is defibrinated and utilised in Turkey-red dyeing, or it is sent to the maker of blood albumin. The fat goes to the fat-melter; the hides of cattle go to the tanner, the feet to the tripe-boiler, and sheep-skins to the fellmonger. The first stomach of cattle and sheep is cleaned for human food (tripe); the second stomach is usually sold as food for dogs or pigs; the heart is

used for human food; the liver and lungs are occasionally so destined, but more commonly are given to animals. The small intestines go to the gut-scraper, the small intestines of pigs being used for sausage-skins; and the large intestines are used for human food. The intestinal contents are sold for manure.

In knackeries, all the soft parts are stripped from the skeletons of the animals; the bones, in turn, being utilised for boiling, like all the rest of the carcass.

The general principles for preventing nuisances arising from slaughter-houses and knackeries are summarised in the rule—observe strict cleanliness. The premises must be conveniently situated, and should not be within 100 feet of any dwelling-house; they should be well lighted, ventilated, drained, and surrounded by a wall to conceal from the view of neighbours all the operations going on within. The slaughter-house should not in any part be below the surface of the adjoining ground. The floors should be impervious (asphalt or concrete), smooth, suitably guttered, and laid with proper slope and channel towards a gully, which should be properly trapped and covered with a grating, the bars of which should be not more than $\frac{3}{8}$ths of an inch apart. The lower 6 feet of the walls should be covered with some impervious smooth material, which can be thoroughly washed with a hose and brush. There should be an adequate tank or other proper receptacle for water, so placed that the bottom shall not be less than 6 feet above the level of the floor of the slaughter-house. No water-closet, privy, or cesspool should be constructed within the slaughter-house. Wherever possible, iron should be substituted for woodwork. Proper receptacles, with well-fitting lids, should be provided for conveying all garbage from, and also where possible for conveying offensive matters to, the works.

Utilisation of Blood.—Blood is utilised for either (*a*) making albumin, (*b*) making manure, or for (*c*) Turkey-red dyeing; all these businesses may be sources of nuisance.

In the making of blood-albumin, the blood is received into shallow pans, allowed to coagulate, the clot separated, and the serum desiccated. In this trade the blood must be fresh, hence there is rarely any nuisance connected with it; moreover, the business is commonly in connection with large public abattoirs, in which space and cleanliness are adequately secured. If complaints do arise, they are due to old material (clots, &c.) retained on the premises until putrid, and to a general unpleasant smell proceeding from the yards, difficult to remove except by the most scrupulous cleanliness. When not directly used for manure-making, all blood-clot should be placed in proper air-tight receptacles and burnt. No dung or other heaps should be permitted on the premises. The clot-room and drying-room are best lighted and ventilated from above; if possible, the air should be drawn off by a fan into a furnace-flue.

Blood-manure is commonly made by mixing blood-clot with impure sulphuric acid. The mixture is dried, powdered, and mixed with other materials, such as superphosphate, and finally dried either in the air or artificially. Nuisance may arise during the mixing of the acid, or during the drying by artificial heat. These operations should be conducted in a covered chamber, from which the acid vapours can be conducted into a flue or into water.

In Turkey-red dyeing of cotton a substance termed alizarin and derived from the coal-tar product, anthracene, is used to obtain the characteristic colour. Bullock's blood is used to fix the alizarin on the cotton, by the coagulation of its albumin. As the blood is always more or less putrid during

the whole of the process, a constant smell exists in and about the dye-works. The nuisance may be obviated by the observance of scrupulous cleanliness, and by conducting the operation in a closed chamber provided with a suitable flue to carry off the offensive vapours under and into a fire connected with a high chimney. In the Model Bye-laws, the following points are emphasised :—(*a*) Blood not in use to be properly stored. (*b*) Pavements to be washed at close of every working day. (*c*) Every empty vessel to be thoroughly cleansed. (*d*) Best means for condensing the escaping gases to be adopted. (*e*) Efficient drainage.

Boiling of Tripe, Trotters, Flesh, &c.—The preparation of these materials as articles of food is a constant source of annoyance. Tripe is the first stomach of the ox or sheep. It is usually emptied of its contents at the slaughter-house, subsequently washed and scalded, and finally deprived of its villous membrane by being scraped with a knife or revolving brush. The tripe is then boiled, either in a boiler or in a pan having a steam-jacket. When cooked it is hung up to drain and cool. The fat is collected for soap-making, and the liquor run off into the drains.

Ox-feet and sheep's trotters are sometimes boiled in conjunction with tripe. They are first roughly dressed, any adherent skin being removed (and set aside for glue-making) and boiled, the fat being collected from the surface and used for making "neat's foot oil." If not intended for food, ox-feet are very carefully prepared so as to avoid waste. The skins are stripped off and treated with lime-water for glue-making ; the hoof is split open and the small deposit of fat found at the ends of the two long bones carefully set aside for "neat's foot oil" making. The hoofs are then washed and boiled ; then finally set aside for the comb- or button-maker. The small bones are used for manure, the long ones for knife-handles, and the liquor either run off into the drain or carefully skimmed for any oil it may contain. Many sheep's trotters are too putrid for conversion into food ; these are limed and then disposed of for manure. It is chiefly from the boiling of these offensive trotters that the main nuisances arise in connection with these industries. Fish-frying is not unusually an offensive trade. In this business the fish are often fried in cotton-seed oil over an open fire. The nuisance arising therefrom is often great, which is not infrequently aggravated by the fish being none too fresh and the constant accumulation of refuse on the premises. The remedy is to use fresh fish, remove refuse matter quickly, and provide a hood over the fireplace connected with a flue to carry off the offensive fumes from the burning oil.

In knackers' yards arrangements usually exist for boiling the flesh of horses and other animals which, while unfit for human food, can be utilised for making cats' meat or grease. The chief sources of nuisance in these places arise from :—(1) general filthiness of the premises, and want of reasonable care ; (2) accumulation of materials, such as carcasses, bones, hoofs, horns, blood, skin, fat, and hair ; (3) seething materials being removed from the boilers, thrown on the ground and emitting noxious smells while they cool ; (4) fumes from the boiler in action, or while being emptied.

These nuisances can be obviated usually by the construction of suitable premises, with boilers so constructed with hopper-lids or other appliances that vapour from them will be drawn up the chimney. The cooling of the meat should be either rapidly carried out in cold chambers, or else be done in properly closed sheds from which the vapours can be readily carried to a flue or chimney. All waste material should be packed in air-tight buckets, and a sufficient staff of workers maintained to prevent excessive accumulations of work.

Bone-boiling is peculiarly offensive, as the vapours generated appear to travel long distances. A further offence arises from the fact that recently boiled bones, when heaped together, evolve an offensive steam possessing a strong musty ammoniacal odour. In this business, as in some of the others already mentioned, there would be less nuisance if the operations were conducted in steam-jacketed pans in place of pans on which the fire plays direct. The other general principles of nuisance prevention in this trade are practically identical with those already enunciated for tripe and trotter boilers. In the Model Bye-laws, it is laid down that :—(*a*) Bones not in use to be stored properly. (*b*) Grease and refuse to be removed from floors at close of every day's work. (*c*) Best means for condensing gases and vapours to be employed. (*d*) Efficient drainage to be secured and all waste liquids to be cool before passing into drain.

Gut-cleaning.—This trade is practically identical with gut-spinning and the preparation of sausage skins. Gut-scraping or cleaning is largely done by women. The small intestines of pigs and sheep are first washed and cleaned of their contents ; they are then softened by soaking in cold salt water for from three to five days ; they are then scraped on a bench by a wedge-shaped piece of wood. The repeated scraping gradually detaches all the interior soft parts, which pass along to go out of the cut end. Finally, only the peritoneum and a little of the muscular structure of the gut is left ; this is then thrown into water. If required for sausage skins, the gut is then simply placed in salt.

For making catgut, lengths of the scraped gut are sewn together with needle and thread ; these, after being steeped in a weak solution of carbonate of sodium for a week, are then spun by means of a spinning-wheel, the thickness of the catgut depending on the number of strands of gut in it. The catgut is usually bleached by exposure for two or three days to the fumes of burning sulphur in a special chamber, after which it is dried by being stretched over pegs in the open air, but protected from sun and rain.

Ballard says :—" Speaking generally, gut-scraping and gut-spinning establishments are the most intolerable of nuisances wherever they may chance to be located." The annoyance from these businesses is often mainly due to their being carried on in places quite unsuited for the purpose. The premises should always be provided with proper stone tables and other appliances ; the storage of material for any length of time should be forbidden, and what material there is should be kept in properly covered and non-absorbent receptacles. The liquor should be deodorised with chlorinated water. The floors, walls, and general principles of construction of premises used for gut-scraping should be on the same lines as already indicated for slaughter-houses. No accumulation of stinking material should be permitted for a moment, and there should be proper vessels for conveying material to and from the place. The cleansing of these establishments must be frequent and thorough ; for nothing will prevent a nuisance unless continuous care be exercised to keep the places clean, and never to allow filth to accumulate. In the Model Bye-laws these points are noticed :—(*a*) Undried and unused guts must be placed in properly constructed receptacles till required for soaking. (*b*) All empty receiving-vessels to be kept clean. (*c*) Floors to be frequently washed and wetted with deodorants. (*d*) Premises to be cleaned at end of each working day. (*e*) Inner surface of work-place to be limewashed four times a year. (*f*) Floor and wall surfaces to be in good repair. (*g*) Good drainage.

Fat-melting, Dip-candle-making.—In these associated trades the materials used are kitchen refuse, dripping, fat, waste meat, and inferior

stuff obtained from the boiling down of bones and scraps at knackeries, tripe- and glue-boiling works, &c. &c. The fat "is melted either in pans (*a*) heated by an open fire, or (*b*) in pans which are steam-jacketed, or (*c*) by free steam and sulphuric acid."

Tallow is either beef or mutton fat or a mixture of both prepared and melted by one or other of the above means. Lard is pig's fat similarly treated. "Moulds" are candles shaped in moulds, and made from mutton suet. "Dips" are inferior candles made by dipping a wick into a melted fat made from inferior tallow.

In these businesses the sources of nuisance are :—(1) the storage of the fats ; (2) melting the fat ; (3) ladling the fat out ; (4) storage of residues, technically called "greaves" ; (5) general filth. As Ballard says :—"The method of preventing nuisance commences at the slaughter-houses. As soon as the fat is removed from the animals it should be laid on racks, and it should not be packed until quite cold and hard." The residue or greaves is usually sold for manure, or, if of a better kind, as food for animals. The chief nuisance arises in the "rendering" or boiling of the fats. The fresher and sweeter the materials used the less is the danger of nuisance during the melting. The great secret in preventing nuisance at this stage is the avoidance of burning the materials, or even raising them to a high temperature. Practically, the temperature need not exceed 120° F. Owing to the residues having to be pressed in order to squeeze out all the fat, a nuisance often arises during the process ; but by conducting the operation under cover, or in a special boxed-in apparatus, or in a chamber provided with a special flue, this source of offence can be avoided. In general terms, the principles of preventing nuisance from these trades are the same as those mentioned in the sections on tripe-boiling, &c. &c. In towns the only permissible method of rendering fat should be by free steam, or in steam-jacketed pans. Melting over an open fire should be forbidden ; and unless fat-melters will adopt proper precautions, they should be compelled to remove from populous districts.

"General cleanliness, the use of good material, melting at a low temperature, and the use of steam and acid to melt the fats are the cardinal points to be attended to with a view to conducting this business without nuisance." For regulating this trade the Model Bye-laws demand :—(*a*) All matters not in use to be properly stored. (*b*) Waste matters to be removed at close of every working day. (*c*) Internal surface of work-place to be limewashed twice a year. (*d*) All inner surfaces to be in good repair. (*e*) Best methods adopted to condense the vapours and gases evolved. (*f*) Good drainage.

Soap-making.—The ordinary neutral fats may be chemically regarded as salts, in which glycerin is the base and a fatty acid is the acid. Soap-making or saponification is the chemical action resulting from the interaction of an alkali (soda or potash) with a neutral fat (tallow), the glycerin or base being displaced and its place taken by the alkali. Soaps are divided into two classes, "hard" and "soft," according to their physical characters. Hard soap has soda for its base, while soft soap has potash.

Soaps are made from fats of all kinds and from resin (colophony) in combination with fats. The business of soap-making has a sanitary interest, not so much on account of the soap itself as of the fats and grease from which it is usually made, and the melting of which is often a nuisance.

The soap is usually made in large pans, set in brickwork, in which the fat or oil or both is placed, and heated either by fire, or better, by free steam discharged into the pans, or by steam contained in pipes surrounding the pan. To the melted fat caustic lye is gradually added, until the materials

have been introduced in proper proportions to form soap. By the addition of common salt the soap floats insoluble and nearly dry on the top of the liquor. This latter is either run off or the soap drawn off from the top. After further treatment with alkali and heat, the soap is run into frames in which it sets in suitable bars or shapes.

Soft soap is made on a similar principle to hard soap, the chief differences being that potash is used instead of soda, and that linseed, cotton, whale, or other oil is used in place of tallow or other grease.

The chief offensiveness in soap-making arises from the manipulation of the fats and oils. Some of these latter, when heated, are peculiarly unpleasant. Nuisance from these causes can be obviated by conducting the melting at the lowest possible temperature, by using pans or boilers with properly fitted lids, and connected with the chimney by a pipe or flue ; or, if necessary, by carrying the vapours under and into the fire or into water. The lid of the pan should have a door through which the boiling can be superintended. In other words, the precautions demanded are identical with those required for fat-boiling. The provisions of the Model Bye-laws on this trade are :—(*a*) Materials not in use to be properly stored in metallic vessels with close-fitting lids, and all empty receptacles to be kept clean. (*b*) The best practicable methods to be employed for condensing offensive gases during boiling or otherwise. (*c*) Drains to be kept in good order, and attention paid to the general cleansing of the premises.

Bacon-curing.—Frequently this is a most offensive trade, owing to the smell generated by the singeing of the hairs of the pig. After the pig has been killed, it is " scalded " and washed, and then scraped to remove the hair, without singeing ; but sometimes the hair is singed before scalding. The stench from the burning hair is very objectionable, and is often unnecessarily aggravated by leaving the carcass still smoking on the premises. A bucket of cold water thrown over it stops the smell at once.

Other sources of nuisance are the fumes from the smoking-chambers where the bacon is dried, and also the brine, in which the bacon has been steeped, being retained on the premises and allowed to decompose. The mode of avoiding this latter nuisance is obvious.

The chief remedy is to so conduct the business in closed chambers that the fumes from the burnt hair and hot steaming carcasses shall be burned or condensed, or both, and then discharged through a furnace into a high chimney.

The preparation of bacon from imported American pork may at times be an annoyance, owing to the warm liquor, in which the pork is steeped, undergoing putrefaction, and being discharged into drains. The process employed consists in first steeping the pork for about twelve hours in water to extract the excess of salt, then drying it in a hot, closed room, warmed by charcoal fires, and subsequently exposing it to a current of air.

Fellmongering and Leather-making.—A fellmonger is one who prepares skins for the leather-dresser. The skins may be either fresh or old (foreign). The fresh skins are beaten with a mallet to free them from dirt, and then soaked and washed in water. The skins are afterwards limed in order to remove the hair. This process finished, the skins are hung up ; and when the hair or wool can be readily detached it is removed by hand. When denuded of hair, the skins are called " pelts." The pelts are thrown into a pit containing milk of lime, and from this pit go direct to the leather-dresser. Foreign skins, being dry and hard, first require soaking. The hair is not removed from them by liming, but by the " tainting " process, or that in which a decomposition occurs which loosens the wool ; at this stage the hair or wool is readily removed by hand.

In fellmongering "the chief nuisance is the storing of large quantities of skins, none of which are absolutely free from adhering portions of flesh, but the other operations can all be done without the creation of nuisance. It is true that large quantities of skins undergoing the 'tainting' process smell, but the smell seldom extends beyond the sheds."

Leather-making consists of two chief stages, "tanning" and "currying." Tanning is essentially a chemical preparation of the skin, or a conversion of the raw putrescible hide into an imputrescible and more or less flexible material known as leather. Currying is the treatment of the leather by means of fatty and other matters, by which it is rendered more soft, supple, waterproof, and generally improved in appearance.

Tanning consists in treating the "pelts," after removal of the lime by washing, with bark or some substance containing tannin. The chief substances used are oak bark, divi-divi (a South American bean), chestnut extract, hemlock extract, valonia (acorn cups from the Levant), mimosa bark, catechu, kino, sumach, &c. &c. The ground tan is placed in pits made of cement, stone, or brick, which are arranged in series so that the skins are passed through successively stronger tan liquors. After removal from the tan-pits, the leather is hung on poles in lofts to dry partially; from these poles it is transferred to heaps or piles on the floor to "sweat." Subsequently the leather is scraped, oiled, and rolled to improve texture and surface, and is often coloured. Some hides are "shaved" or reduced in thickness by splitting. "Soft leathers, such as glove kid, are not tanned, but 'tawed,' in which process treatment with alum and salt is the chief means employed."

In the currying processes the leather undergoes further steeping, heating, stretching, and drying. After this it is oiled; various kinds of oil are used, such as whale, castor, cod-liver, linseed, &c. &c.

The sources of nuisance from tanneries are various. The chief arise from solid waste, hair, bits of flesh, fat, skin, &c., as well as from the *débris* from the bottom of the lime- and tan-pits. In the preparation of certain superior kinds of leather the pelts are placed in so-called cleaning-pits, which contain dung or urine. These liquors have usually an abominable odour, and unless the process is performed in a suitable shed, so constructed that the contaminated air passes into either a tall chimney or through a fire, a nuisance is certain to be created. To these possibilities of offence must be added the possibility of the presence of arsenic in skins which have been roughly cured abroad. Wash-water from these skins, treated with arsenic and lime, readily generates sulphuretted hydrogen, sulphide of arsenic, and subsequently arsenious and sulphurous acids. The dangers from these poisons are best obviated by adding salts of iron, which form insoluble arseniates.

The remedies for the chief sources of complaint in respect of fellmongeries and tanneries follow lines more or less indicated for other trades of this kind. The first essential is the construction of premises adapted to the business. The more carefully they are so adapted to the work the less likelihood is there of a nuisance arising. All pits should be water-tight, and the floors around smooth, impermeable, properly sloped, and well guttered. The walls of the building should be of hard smooth material, so that they do not absorb dirt, and can be frequently washed. The whole of the premises should be freely open to the air and light. The conveyance of all offensive skins and other *débris* to and from the tan-yard should always be in covered carts. A plentiful supply of water should be at hand, with a hose, as well as ample conveniences for the workpeople to wash

themselves. The Model Bye-laws insist on the following points :—(*a*) Useless and decomposing skins to be destroyed. (*b*) Pavements to be swept at end of each working day. (*c*) Tables, benches, knives, &c., to be frequently cleansed and disinfected. (*d*) Refuse flesh, skin, hair, horns, and hoofs to be collected and stored for removal. (*e*) Tank-water to be run off so that no effluvia is emitted; all washing or soaking tanks to be emptied daily. (*f*) Waste lime to be removed quickly in suitable vessels. (*g*) Every part of premises to be scraped and walls washed with hot lime twice in the year. (*h*) Floors to be in good repair. (*i*) Drainage to be efficient.

Glue-making.—This important article is obtained by boiling bones (after the fat has been extracted), hoofs, horns, scraps cut off during the preparation of skins for leather, scraps of leather, parchment, &c. ; in fact, from nearly every kind of waste animal tissue. "These various materials are first 'limed' and the lime afterwards well washed out with water. The matters are then boiled, the fat being skimmed off the top, and the warm liquid glue run into shallow troughs and allowed to solidify. The solidified mass is then cut up into slices."

The character of the materials used in this business readily suggests the possible nuisances which may arise. The effluvium from the boiling process, in particular, is often most offensive ; to this must be added the smell which emanates from the *débris* from the vats, after the glue has been drawn off, and commonly called "scutch." If this "scutch" be allowed to accumulate, the resulting odour is intolerable. The sooner it is barrelled and removed the better. In order to remove fat from it, the "scutch" is treated with hot water, or cold water with steam, and the fat skimmed off, the residue being pressed in coarse canvas to extract the least remnant of grease. The cake is used for manure. If kept dry and under cover, "scutch" will keep inoffensive for some time, but if allowed to accumulate in the open air it soon becomes offensive.

Nuisance may result from accumulations of raw material before use ; this can be obviated by stacking and covering each layer of a few inches thick with lime ; above all things, it must be kept dry. To avoid smell from the boilers, the vapour should be conducted under and into a fire and burned, or into a scrubber where it would be washed and condensed. It should always be conducted finally into a tall chimney. The Model Bye-laws contain these provisions in regard to this trade :—(*a*) Decomposing matters not to be kept longer than necessary; all moist material to be properly stored. (*b*) Offensive gases from boiling vats to be condensed. (*c*) All materials to be dried before entering the part of the premises used for storing *dry* material; when weather interferes with drying, then treat with milk of lime before stacking. (*d*) Refuse from boiling-pan to be collected and not to remain on premises more than forty-eight hours ; boiling-pan to be frequently cleansed. (*e*) Waste lime to be removed. (*f*) Work-place to be swept every day, and the packing- and drying-rooms every week. (*g*) Inner surface of premises to be kept in good repair and the walls limewashed once a year. (*h*) All drains to be in good order.

Artificial Manure-making.—This is a very large trade, and utilises an enormous quantity of material which otherwise would be wasted. The artificial manures are known by such terms as "blood manure," "bone manure," "superphosphate," "poudrette," &c. &c. The materials used in the making of these artificial manures are of the most varied kind, and include :—the *débris* of knackers' yards, offal from tanneries, tripe and trotter boilers, glue-works, scutch, shoddy, hair, bones, bone-ash, night-soil, coprolites, fossil remains, animal charcoal, soot, gypsum, burnt tar,

and certain salines, such as sulphate of ammonia, common salt and nitrate of soda.

During the process of manufacture, impure sulphuric and hydrochloric acids are largely used. These acids are stirred up with the dry material until a thick paste-like mass is produced, the consistence of which varies. "Superphosphate" is prepared from a mixture of mineral phosphates and ground bones, treated with sulphuric acid. "Poudrette" is the name of a manure in the form of a dry powder, prepared from night-soil treated with sulphuric acid.

It is obvious that the general atmosphere of works devoted to businesses of this kind is always more or less impure. Nuisance is often complained of before the materials reach the works, owing to the stench caused during their conveyance there. This can be obviated by their being brought as far as possible in a fresh state, and always contained in air-tight receptacles. The highly irritant vapours which arise in the mixing and manipulation of the materials should invariably be either condensed and run into the drains or be carried to tall chimneys provided with efficient furnaces, while the whole of the operations should be conducted within large, airy, but closed buildings.

Oil-cloth- and Linoleum-making.—Oil-cloth is made of coarse canvas, which is first coated with size and afterwards covered with a coating of very thick paint, laid on with a trowel and well worked in. Both sides of the canvas are treated in this way; and when one layer is dry, additional ones are similarly applied. Finally, the pattern is printed on. In place of size, frequently blood and lime are used. The drying is usually conducted in rooms artificially heated to 180° F.; and during this stage of the process very offensive vapours are given off.

Linoleum consists really of finely powdered cork mixed with linseed oil, and rubbed up into a kind of cement with resin and kauri gum. "These ingredients are heated together in a steam-jacketed pot, provided with stirrers and an air-tight lid, a pipe from which conducts the vapours into the furnace." After being rolled this cement is ready for use, about 46 lb. being mixed with 56 lb. of the ground cork. Colouring-matter is added, and after further mixing the compound is rolled out into sheets, and finally applied to the canvas made of jute. Only one surface of the canvas is thus covered, the other surface being protected by a layer of "backing," made of size and pigment or varnish.

In this business there is some danger of explosion, both during the powdering of the cork and when the cork and cement are mixed. The cement may take fire spontaneously, and also the fine dust floating in the air is liable to ignition.

Similar nuisances may arise in both these trades, and are due to the vapours given off by the hot oil. In the drying-rooms of oil-cloth factories it is hardly possible to breathe after the cloths have been drying for some hours, and the vapours often extend over considerable distances. The only remedy is to propel the vapours by means of a fan into the furnace, the process being greatly assisted by previously passing them through water.

India-rubber-making.—In this manufacture and in vulcanising, offensive odours of sulphur compounds are caused, intermingled with those of tar-oils, &c. The crude rubber is boiled, washed, and incorporated with sulphide of antimony or sulphur. It is subsequently vulcanised by either the American process, which is chiefly mechanical, or by the English process, in which naphtha is used as a solvent. Ballard gives the processes

concerned in creating nuisance to be :—(1) the boiling of the rubber; (2) the use of naphtha; (3) the discharge of steam from the vulcanisers; (4) the drying of sheets of vulcanised india-rubber upon steam-chests after washing them, the process giving an odour of burning rubber.

The means to be adopted to prevent these nuisances are :—to conduct the boiling operations in covered vessels, to use a ventilating fan, and to pass the effluvia through a heated furnace.

Varnish-making and Oil-boiling.—Varnish may consist of :—(1) "drying oils," which become hard and resinous by oxidation in the air; (2) of oil varnishes made of a resin and a drying oil; (3) of compounds of gums, resins, &c., in a volatile liquid, which by evaporation leave the precipitated solids as a glassy coating. The principal resins used are copals, dammar, animi, and kauri, &c. All oils have not the same properties as drying oils, linseed oil being the most important of the commercial drying oils. This valuable property of drying or oxidising is increased by exposure to the air in a thin film; by heating, or, as it is called, boiling; by the addition of "driers" or substances which hasten desiccation by parting with some of their own oxygen, or acting as carriers of atmospheric oxygen; the chief of these are sulphate of zinc, peroxide of iron, and protoxide of lead. The two latter are true oxidisers, while the first acts by assisting the separation of vegetable albumin and other substances which hinder the drying.

The actual processes employed in these businesses are practically those of melting and fusion. The vapours given off are very pungent and irritating, affecting the eyes and causing headache, malaise, nausea, and vomiting. The essential agent in these offensive and far-reaching vapours is acrolein, which is a product of the decomposition of glycerin. It is a light, volatile liquid of low specific gravity, with a boiling-point of about 120° F.

The only effective method of preventing nuisance is to have the pot in which these materials are heated covered with a hood, from which a pipe, provided with a fan, conducts the vapour into a fire. The nuisance is usually so great that a special hot coke fire, connected with a high chimney, should be provided to destroy these vapours.

Paper-making.—Paper is now made from a variety of substances, such as waste paper, old rags, hemp, old ropes, straw, wood made into pulp, canes, bamboo, and esparto grass. The collection and storage of old rags and waste material of this kind is a constant source of menace to the public health, and constitutes an important sanitary question. Apart from this, they may heat and ignite spontaneously through slow combustion.

The preliminary preparation of rags and paper for paper-making consists in dusting them in an "agitator." After this they are cut into small pieces by hand and again dusted; after which they are boiled with carbonate of soda or caustic soda, or a mixture of both. Next they are bleached either by chlorine in a closed chamber or by the alternate application of bleaching-liquid and acid. Their subsequent treatment does not differ from that of esparto grass.

Esparto grass, after a preliminary cleaning by picking out of impurities, is boiled with a caustic alkali in a closed boiler into which steam is forced under pressure. The resulting liquor is always very foul, and if not turned into the nearest stream is run into a store-tank. From this, by subsequent evaporation and incineration of the residue, soda is recovered, and constitutes a valuable economical operation. From the esparto or rag pulp, paper is eventually made by a series of mechanical procedures which do not suggest sanitary questions.

It is the esparto liquid which is the chief source of nuisance and offence. It has the colour of strong tea, is alkaline, strongly reducing, and emits a most offensive odour. It should never be permitted to be run into any stream or ditch near habitations. Annoyance commonly arises from the vapours given off during the boiling processes and from the mass of pulp while cooling. But the recovery of the soda usually leads to a greater nuisance, partly from the vapours yielded by the evaporation, but still more from the pungent empyreumatic fumes produced by the ignition of the residues from the store-tanks.

All vapour should be conducted by a flue into a tall chimney, while the fumes produced during incineration should be conducted under and into furnace fires.

Some sanitary dangers exist in the employment of poisonous colouring-agents for paper, but their effects are less apparent in the actual industrial processes than upon children and others handling or sucking the finished article. The use of poisonous colouring-matters needs to be absolutely forbidden, as being both dangerous and unnecessary.

Manufacture of Alkali.—This industry has been the subject of special legislation, more particularly with reference to the gases and acid fumes which are produced. Improvements in apparatus for washing the issuing gases have materially reduced the prevalence of nuisances from this cause ; moreover, the administration of the Alkali Act, being supervised by special inspectors, has largely removed this matter from the domain of the Sanitary Officer.

Apart from this, however, the industry in certain special features directly concerns the Sanitary Authorities, owing to nuisances which arise from what is known as " tank waste." To appreciate the nature of these possible nuisances, it is necessary to refer briefly to the materials used in the actual manufacture of alkali.

These materials are common salt, sulphuric acid, limestone, and coal. The salt is decomposed by sulphuric acid and heat, resulting in the production of sulphate of soda with liberation of fumes of hydrochloric acid. The sulphate is mixed with limestone and coal and heated, the ultimate product being a mixture of unburnt carbon, sodic carbonate, and calcium sulphide ; the former gives the whole mass a black colour, hence the name of " black ash." If this black ash be treated with water, the sodic carbonate is dissolved out, leaving a residue known as " tank waste."

The main " source of nuisance from these waste heaps is the soluble matter which is a sulphuretted compound of calcium of indefinite composition, but which is mainly composed of sulphide of calcium, partly converted by oxidation into hyposulphite of calcium, and holding in solution with it a considerable but indefinite quantity of sulphur." If these waste heaps, from rain or any other cause, become moistened, they are liable to emit large volumes of sulphuretted hydrogen, which are a constant nuisance and offence. In recent years some success has attended efforts made to so utilise the waste that the sulphur contained in these heaps may be extracted by appropriate chemical treatment. The processes adopted, in theory, should not produce any nuisance, but practical experience shows that sulphuretted hydrogen is not unfrequently evolved, with the result that the control and management of these mounds of black ash waste in the vicinity of alkali works still constitute a frequent source of anxiety to Sanitary Authorities in whose districts they are situate.

Other Trades associated with the Generation of Irrespirable Gases.—In addition to the foregoing, there are a number of other

businesses which possess the common feature of generating more or less of certain gases which are not only offensive to the smell, but which produce readily or immediately great irritation of the respiratory passages. Among industries of this kind we may mention more particularly the manufacture of oxalic acid from sawdust, the distillation of wood for the purposes of obtaining wood naphtha and pyroligneous acid, the making of coal-gas, the distillation of tar, the manufacture of carbolic acid, the making of sulphate of ammonia and sal-ammoniac from the ammoniacal liquor of gas-works, the making of sulphuric acid and salt, the manufacture of chloride of lime and of glass, tin-burning and the making of tin-plates, copper-smelting, the calcining of arsenical ores, the making of coke and breeze, lime-burning, ballast-burning, the firing of pottery, and the making of bricks and of cement. These latter two businesses have been mentioned already elsewhere, on page 160; the others, while involving the use of materials largely differing from each other, have this in common, that in the greater number the causes of offence and nuisance are such gases as chlorine, sulphurous acid, sulphuretted hydrogen, nitrous acid, carbon monoxide, carbon dioxide, marsh gas (methyl hydride), and olefiant gas (ethylene).

Among remedial or preventive agents free ventilation takes the first place; supplementary to it may be mentioned the employment of flannel respirators damped with water, or, in the case of chlorine fumes, with a solution of sulphite of soda. Practically, in the majority of these trades the best mode of preventing danger to health is to pass the deleterious vapours from kilns and other generators by a suitable hood and flue, assisted by a fan if necessary, through a furnace, and thence into a tall chimney. In some cases attempts may be made to deal with the nuisance by condensing and washing the fumes in a cold-water scrubber, or by passing them through absorbent media, such as sawdust, alkalies, milk of lime, and oxides of copper or iron; or through oxidising media, such as lead and manganese dioxide. Even these methods, however, are not always successful.

Manufacture of Horse-hair.—A large industry exists for the preparation of hair for mattresses, chairs, brush-making, &c. The hair so used is not limited to that of the horse, as cow- and pig-hair are also employed. The manes and tails of horses and the tails of cows are the parts chiefly used. Except the best quality of horse-hair, all these are more or less filthy and dusty, from the intermixture of dung, pieces of skin, and earth.

The first procedure is to sort the hair into the long and short, the coloured and the white; usually this is a very dusty operation. The hair is then washed, and when dry is combed; this latter process removes the short hairs which have been previously overlooked.

The long white hairs are bleached by exposure to burning sulphur in a closed chamber; the long coloured hairs are dyed, usually black, with logwood and protosulphate of iron. The short hairs are sometimes dyed and sometimes not. If very dirty they are teased and dusted in a "willeying" machine; the resulting fine dust is commonly discharged into the air instead of into a furnace-flue; the heavier dust is utilised for manure.

The short hair, when dyed, is commonly so treated with the dirt on; sometimes it is winnowed first. The hair is curled by being twisted into a sort of rope by a curling-machine; it is then steeped in cold water, and on removal placed in ovens at a high temperature, after which the curl is permanent.

The chief sources of nuisance in connection with hair-works are the stench from the vapours of the dye-vat, and from the hot liquor discharged

into drains. The statutory limit of temperature, above which liquids are inadmissible into sewers, is 110° F. The only remedy against the stenches from the dye-vats is the use of a water-sealed lid, with hood and a flue conducting the vapours into a scrubber or cold-water tank. Mere discharge into a chimney is rarely effective against annoyance. Wearing a respirator by the workpeople appears to afford but a comparatively slight protection, as disease is not infrequently contracted by inoculation through abrasions of the skin. As regards the nuisance from the discharge of hot liquors into drains, the only remedy is not to discharge them until cold.

Another evil in connection with this industry is the possibility of infection with anthrax. During the fifteen months ending March 31, 1907, there have been seventeen cases of anthrax reported in connection with the handling of horse-hair. It is due to infection by means of virus attached to the hair from animals which have suffered from the disease, and is practically identical with the subject of the succeeding section upon wool-sorting. The more recent regulations from the Home Office arrange for the disinfection of all horse-hair, except white and light grey hair which might suffer damage in the process, before undergoing any process other than sorting. This is a most important procedure and a step in the right direction.

Wool-sorting.—A wool-sorter is a person who divides the wool of a fleece into "sorts" or classes of various qualities, that is, the coarser and finer portions are placed apart in separate bundles. In connection with the woollen industry this sorting constitutes an important form of labour. When a dry, dusty material is being sorted, such as mohair, alpaca, and camel's hair, there is always much dust in the air of the sorting-room ; but when sheep's wool is being sorted, owing to the greasiness of the fleece, this is not the case. The sorting of wool is usually performed over a movable wire grating covering an opening, through and into which dust and the other fine matter falls. Dust is generated not only during the actual sorting of wool, but also during the opening of bales or other large packages of wool.

Owing to the prevalence of anthrax, malignant pustule or charbon among certain animals, a great liability to the infection of this disease exists among herdsmen, skinners, slaughtermen, unloaders of cargoes of hides, and the manipulators of various wools and hairs. In this respect, the most dangerous wools imported into this country are those from the districts around Lake Van and from Persia. There is liability to infection by the spores and bacilli of anthrax in any of three ways—either by inoculation through wounds of the skin, by swallowing, or by inhalation. In serious cases a fatal termination may result in twenty-four hours, and is rarely postponed beyond three to four days. In other cases the attacks are relatively slight.

In 1905 there were twenty-four reported cases of anthrax. Thirteen were connected with the woollen industry, eight with the handling of hides and skins, and three from horse-hair. Inquiry showed that the occurrence of anthrax in the combing- and carding-room was not due to the processes carried on in these rooms, but to the conveyance into them of infected dust from unwashed dangerous wool outside ; defective arrangements in connection with the willeying machine caused the dust to be drawn across the workers' faces. The remedy appears to lie in the disinfection of the hair before sorting, by submitting it to the process of boiling and dyeing before dealing further with it.

As illustrating the sanitary precautions necessary in the conduct of this business, the following regulations, modified from those originally drafted

by Whiteside-Hime, and adopted by the Town Council of Bradford, may be conveniently quoted in this place :—

1. All bales of wool or hair shall be opened by some person skilled in judging the condition of the material. If he find the contents unobjectionable, they shall be sorted in the ordinary way. If, on opening any bale, dead or fallen fleeces or damaged materials are found, such bale shall be at once taken from the room where opened, and dealt with as noxious. All Van, Persian, damaged wool, fallen fleeces, and foreign skin, wool, or hair shall be deemed noxious, and shall not be opened in the sorting-room. All wool or hair shall, before sorting, be thoroughly saturated with water and then washed in hot suds, rolled and sorted while damp, or if steeping would be injurious to the article, then it shall be disinfected.

2. No noxious material (alpaca, pelitan, or East Indian cashmere) shall be opened in the sorting-room, but in a place specially set apart for the purpose, separate and distinct from the sorting-room, and all such material shall be opened over a fan by some person capable of judging the condition of the material.

3. The sorting-rooms for all dry and dusty materials shall be provided with extracting fans so arranged that each sorting-board shall be independently connected with the extracting shaft, in order that the dust arising from the material being sorted may be drawn horizontally or downwards, and thus prevented from injuring the sorter.

4. The dust collected by the fan must not be discharged into the open air, but be received into properly constructed catch-boxes. It must be afterwards burnt. The catch-boxes should be emptied at least twice a week. The sweepings from floors, walls, and from under the wire gratings or " hurdles " shall be similarly treated. All pieces of dead skin, scab, and clippings must be removed weekly from the sorting-room, and must not be dealt with or sold until they have been disinfected.

5. All bags or coverings in which wool or hair has been imported shall be picked clean and not brushed, and such bags shall not be sold or used for any other purpose until they have been disinfected.

6. No sorter having any exposed open cut or sore upon his person shall be allowed to sort.

7. A suitable room, outside the sorting-room, shall be provided in which the sorters can leave their coats during working hours.

8. Proper provision shall be made for the keeping of the sorters' food out of the sorting-room. No meals shall be taken in the sorting-room.

9. The sorting-rooms shall be well ventilated, by fans or otherwise ; but as this cannot be effectually accomplished by open windows only, power shall be employed to secure downward or horizontal ventilation, so arranged as to protect the workmen from draught. The sorting-rooms shall be warmed during cold weather. Windows shall be kept open during meal hours.

10. No wool or hair shall be stored in the sorting-rooms.

11. The floor of the sorting-room shall be thoroughly sprinkled with a disinfectant, so as to allay dust, and swept daily after work is over. The sorting-room shall be thoroughly disinfected and the walls thereof limewashed at least once a year.

12. Requisites for disinfecting and treating scratches and slight wounds should be at hand in the sorting-room.

13. Proper provision shall be made for the sorters to wash in or near the sorting-room.

14. A copy of these precautionary regulations shall be hung up in a conspicuous place in every sorting-room.

Trades Associated with the Use of Poisonous Metals.—There are practically six metals used in the arts and manufactures which more or less affect the health of the workers in them ; these metals are arsenic, chromium, lead, mercury, phosphorus, and zinc.

" *Arsenic* is generally recovered from its ores by roasting, or by being exposed to a current of heated air in a reverberatory furnace, arsenious acid being formed. This is carried off as a vapour into long flues where it is precipitated." Metallic arsenic is rarely used except in the making of shot, to give hardness. The emptying of the flues or chambers in which arsenious acid has condensed is a dangerous operation for workmen, necessitating the adoption of special leather suitings and head-pieces in which to work.

Arsenic enters largely into the composition of pigments, more particularly Scheele's green, Vienna or Schweinfurth green, and King's yellow ; it is also much used in the preparation of artificial flowers. Absorption of the poison may take place through a mucous or raw surface, and even without any solution of continuity of the skin.

Prevention of poisoning depends largely upon the personal hygiene of the

workmen, who should maintain great personal cleanliness, avoid taking any food or drink in the workrooms, regularly change their clothing before leaving the workshops, shave the face daily, and keep the hair short. All arsenic works should have suitable condensing chambers and be adequately ventilated. No water containing arsenic should be discharged into either sewers or streams. All persons who show symptoms of being affected by arsenic, no matter how trivially, should be at once removed from the influence of the poison.

Chromium salts are chiefly employed in calico-printing and calico-dyeing; they are also used in mordanting wool and in the dyeing of silk and linen, as well as in glass and porcelain painting. Poisoning follows the swallowing of small quantities of these chrome salts, the symptoms being not unlike those of poisoning with arsenic or mercury. The danger following the industrial use of the chromates depends less upon the risk of swallowing them than upon their action on the skin and mucous membranes, where they cause destructive ulceration. The pulverising of the chrome ironstone, which is the principal ore of chromium, does not appear to produce these specific injuries, but is chiefly objectionable by virtue of its being a dust. On the other hand, grinding of the chromates is particularly offensive. The fine dust falls on the skin and adheres to moist parts, which it quickly irritates, acting with the greatest severity on the nasal mucous membrane.

These latter effects are minimised by the use of respirators soaked in a solution of bismuth, which forms with chrome dust an insoluble compound. At all times the operation of pulverising these dangerous salts should be done in a closed chamber, provided with well-fitting glass windows to allow of observation of the progress of the work. The chimneys of all calcining ovens must be furnished with means to draw off the dust and fumes into suitable chambers, in order to prevent destruction of neighbouring vegetation and injury to men and animals. Care needs also to be taken that pollution of ponds, rivers, and rain-water does not occur.

Lead is used in a great variety of industries, and constitutes a most important article of commerce. Poisoning by this metal is also far from uncommon, since it is introduced into the system either by direct absorption through the skin or mucous membranes, or by the inhalation of the vapour or powder produced in certain stages of its manufacture.

Among the more important industrial operations in which danger from lead-poisoning is liable to arise are:—varnishing of leather, and the imparting of a glaze to visiting and playing cards; the making of artificial flowers, leaves, and jewels; the weighting and dyeing of silk and alpaca; the preparation of lace and straw hats; the preparation of paints; calico-printing and dyeing; the glazing of pottery, bricks, &c.; the enamelling of iron plates and hollow-ware; file-cutting, glass-cutting, type-founding, and type-setting. Lead-mining operations are not, as a rule, characterised by any special danger of lead-poisoning. During the smelting of the ore, however, the risks are greater, as there is always more or less of vaporised lead given off with the sulphur dioxide. For this reason, smelting always necessitates the use of condensing chambers, and the application of water in the form of either a shower-bath or steam.

In the making of red lead much dust is produced; and the escape of dust or vapour from the furnaces requires constant control. The grinding of the minium is also attended with danger, necessitating the use of closed chambers. As regards white lead or the carbonate, the manufacture is much more dangerous when carried out by some processes than by others. Three processes are in common use:—(1) Thénard's method, by which the carbonate

is developed directly by the action of carbon dioxide on the lead ; (2) the Birmingham method, in which the carbon dioxide given off in the combustion of coke is utilised for the same purpose ; (3) the Dutch method, in which acetic acid is slowly volatilised in pots, on the top of which thin sheets of lead are placed. The lead is oxidised so as to form a subacetate of lead ; this is again decomposed by carbon dioxide evolved from quantities of tan in which the pots are placed, the whole collection of pots piled one on the top of the other being technically known as a " stack."

This Dutch method is still the most extensively used and is distinctly the most dangerous. When the conversion of the lead into a carbonate is complete, girls enter the stack, place the white lead in trays, and carry these first to rolling-mills and subsequently to drying-stores, kept at a temperature of 200° F. After being dried, the white lead is ground, washed, and then dried to a very fine powder. The women engaged in removing the white lead, and in the various storing, grinding, and packing operations, are the chief sufferers from plumbism in this industry.

Among the important preventive measures to be adopted by workmen are, the wearing of gloves and the inunction of the hands and face with oil or grease. The conveyance of the carbonate from the stacks should be effected with care and, if possible, by covered shoots. The grinding should be performed by rollers in a closed chamber, fitted with an exhauster to draw off the dust into a condenser, water-bath, or other receptacle. Wet grinding would mitigate many of the evils here indicated.

The committee appointed by the Home Office to report on the employment of compounds of lead in the manufacture of pottery (1899) states that no practical difficulties result in the pottery and allied trades from the general substitution of " fritted lead " for " raw " lead. Such a compound may be made by " fritting " an intimate mixture of litharge, flint, glass, borax, china clay, and ground flint. In the interest of the public, as well as that of the worker, they recommend that the amount of " fritted " lead in the dipping-trough, calculated as lead monoxide, should not exceed 12 per cent. of the dried materials. They further recommend that the use of " raw " lead should be absolutely prohibited, and that young persons and women should be excluded from employment as dippers, dippers' assistants, ware-cleaners after dippers, and gloss placers in factories where lead glaze is used.

The personal hygiene of the workmen is of the first importance, and above all, personal cleanliness is essential. Clothes should be made close fitting at the neck and wrists, and what is worn in the workshop should be left there and another suit worn at home. The use of warm baths should be encouraged, and on no account should any food, solid or liquid, be taken until the mouth is rinsed out with water, the hands washed, and the teeth brushed. If circumstances prevent workmen leaving the premises at meal times, they should be provided with a room for meals distinct and detached from the workplaces. No workman who has already shown a predisposition to plumbism should be allowed to continue the work ; and all persons having open sores should be excluded from the workshops. The drinking of acidulated drinks, or the constant taking of iodide of potassium, should be discouraged. Small doses of sulphur, as favouring the formation of an insoluble sulphide of lead, may be taken advantageously ; in a similar way, the freely drinking of milk may be of use. The cleanliness of the workshops is as important as that of the workmen. They should be kept free from dust by constant sweeping and washing, while the floors may be constantly moistened with either chloride of calcium in solution or by water. A

periodic medical examination is required under special rules for all processes in which lead is used. Lead-poisoning is one of the diseases in which notification by the medical practitioner is compulsory under the Factory and Workshops Act.

Mercury is another important article of commerce, chiefly met with as the sulphide or cinnabar (vermilion) and sometimes as calomel or subchloride. Among the trades in which mercury in some form or another is used, and in which danger arises to the workpeople, may be mentioned the following :—

Bronzing, or that business in which plaster objects are given a metallic appearance by rubbing them with an amalgam consisting of equal parts of mercury, tin, and bismuth, and subsequently varnishing them. In hat-making the skins are often rubbed with a coarse brush, damped with a 10 per cent. solution of acid nitrate of mercury (a process technically known as *carrotting*). In the subsequent operations of shaking, clouds of mercurial dust are spread about, to the great danger of the workpeople, among whom mercurial poisoning is not uncommon. This sequence of events is also frequent in the operations of preserving and stuffing the skins of animals, from the fact that an arsenical soap and corrosive sublimate are largely used. These materials, on desiccation, generate a dust which permeates all the workrooms and may cause all the symptoms of poisoning by these metals. Gilding, in which a mercurial gold amalgam is employed, is another dangerous occupation, the workpeople being liable to intoxication, both during the preparation of the amalgam and in its application to objects to be gilded. The manufacture of incandescent electric lamps, where mercurial pumps are used to produce a vacuum, and electrical engineering, mercury being used in amalgamating zinc plates, are dangerous occupations, as mercurial vapours are largely volatilised during all these operations. Artificial flower-makers are also exposed to the danger of mercurial poisoning, owing to the employment by them of the dangerous mercurial pigments, such as the chromate, the biniodide, and the sulphide. Photographers, electric battery-makers, and also those engaged in making thermometers and barometers, are all exposed to risks of mercurial poisoning, the liability to this being all the greater, as mercury is a metal so volatile that it gives off vapour at all temperatures, and can undoubtedly be absorbed through the unbroken skin.

The sanitary precautions demanded in these mercurial trades necessarily follow closely those already detailed in the case of analogous businesses in which lead is used. All condensing chambers and flues employed in extracting the native cinnabar from the ore must be constructed so as to prevent the escape of fumes or gases. Workmen should be provided with long overalls to protect their clothes from mercurial dust ; great cleanliness should be maintained by frequent washing, especially of the hands, face, and mouth. Chambers where mirrors are silvered need to be well ventilated, the outlets being placed below, as the hurtful vapours and dust are heavy ; similarly, in handling the amalgam, gloves should be worn and all vessels containing mercury should be kept covered, to minimise as much as possible the volatilisation of the objectionable vapours.

The diffusion of ammoniacal vapour in mercurial workshops has been said to be productive of much good in purifying the air of these places, but the *rationale* of the procedure is not very apparent, as metallic mercury does not combine with ammonia. Owing to the constant spilling of mercury on floors during the various operations of these trades, floors should be of impermeable material, sloped, and provided with gutters from which the

metal can be readily collected. In some places it has been found an advantage to have on the floors of workshops and elsewhere quantities of tin-foil or other metal, which, by readily forming an amalgam, reduces loss by waste and also lessens the danger of volatilisation.

Under the provisions of the Factory and Workshop Act, 1901, section 73, it now becomes the duty of every medical practitioner to notify to the Chief Inspector of Factories at the Home Office every case of mercurial poisoning contracted in a factory or workshop which he attends, or is called on to visit.

Phosphorus, both as yellow phosphorus and in its amorphous (red) form, is used on an enormous scale in various manufactures. For industrial purposes phosphorus is prepared from bone-ash, the latter being decomposed by sulphuric acid, sulphate of calcium being formed. Most of the phosphorus is found in the liquid as superphosphate of calcium. The liquid is evaporated to the consistence of a syrup, then mixed with one-fourth its weight of charcoal and dried by heating in an iron vessel. The resulting dry mass is heated to redness, half the phosphorus distils over and is collected into the water, while the other half remains combined with calcium in the retort as pyrophosphate. At this stage the phosphorus is impure, containing compounds of arsenic, carbon, sulphur, silicon, and red amorphous phosphorus. It is subsequently purified by either pressing, when heated under hot water, or by chemical treatment with bichromate of potassium and sulphuric or nitric acids. It is usually sold in the form of sticks, the melted phosphorus being sucked into glass tubes.

The red or amorphous phosphorus is formed by heating phosphorus in a closed vessel. It consists of red scales, and does not become ignited on coming in contact with the air until it reaches a temperature of 260° C. or 500° F., when it becomes reconverted into the ordinary form. This red phosphorus is largely used in the preparation of " safety " matches.

During the purification of phosphorus arseniuretted and sulphuretted hydrogen, also phosphuretted hydrogen and phosphoric anhydride, are given off in large quantities. Hence great precautions need to be taken by workmen to avoid risks involved in the inhalation of these fumes. The manufacture of red phosphorus may lead to the development of similar gases, owing to the impurities in the phosphorus which is used for conversion into the red form. The most obvious sanitary precaution in all these operations is the careful closing of the digester, the making of it air-tight, and the exercise of care during opening to avoid the escape of the noxious fumes.

The chief business in which phosphorus is employed is that of making matches. After being cut to the required shape and size, the wooden stems of the matches, to the number of from 3000 to 6000 at a time, are fixed in a frame, warmed on a hearth and then dipped to the required depth into melted sulphur, whose temperature is not much above 235° F. By giving the frame a shake, the superfluous sulphur is removed ; the sulphur-tipped stems are next dipped into the igniting material ; this material is formed of white phosphorus, which should not amount to more than 8 per cent. of the mass, though in England the proportion is usually much larger, melted under hot water and mixed with oxidising materials (such as peroxide of manganese, nitrate of potassium, litharge, or even chlorate of potassium), and some kind of material to fix it on the match (usually glue or gum), and some colouring-matter (such as umber, aniline colours, or ultramarine) ; this mixture is used either hot or cold. Subsequently the matches are left in the frames in warm air (85° F.) until they are quite dried, when they are taken out of the frames and made up in bundles or put direct into boxes.

Many "non-safety" matches are made now with what is known as Schwiennig's powder. This may be described as a mixture of the material contained on the heads of the Swedish matches and of that which is pasted over the striking surface, thus avoiding the objectionable yellow phosphorus and substituting for it the harmless red amorphous variety. The success of Schwiennig's powder depends on the presence of calcium plumbate, which prevents spontaneous ignition. The decomposition of this salt provides the oxidising agent, lead peroxide, while the calcium base aids in the development of a high temperature by neutralising the freshly formed sulphuric and phosphoric acids. The calcium plumbate acts also as a negative catalysing agent, that is, it reduces the velocity of the reaction and affords slow combustion instead of irregular explosion. Matches made with this powder do not ignite spontaneously until a temperature of 155° C., has been attained, whereas the ordinary phosphorus match gives off noxious fumes at 60° C.

In "safety" matches, the red phosphorus which is employed for them is contained in the rough rubbing substance on the box, and not in the igniting material on the match-heads. This igniting material is fixed by glue to the matches, and is composed of chlorate of potash (10 to 40 per cent.), iron pyrites, peroxide of manganese, powdered glass, sulphide of antimony, and some adhesive matter, such as glue.

The dangers attending the purification and distillation of phosphorus have been mentioned. The storage and carriage of phosphorus demands care. It should always be kept in glass or stoneware vessels containing water, and be placed in cool chambers away from all risk of breakage. For transport, all the vessels should be provided with handles, and be invariably labelled to show which is the upper side.

As might be expected, the operations of match-making are by no means free from danger. This arises from the presence of phosphorus in the match-heads, and from the sulphur employed as a medium between it and the wood. Owing to the constant evolution of sulphurous acid, the pans in which the sulphuring is done should be covered with a proper lid, and be provided with a pipe to conduct the fumes into a tall chimney. Owing to the danger of explosion, the preparation of the igniting material must be conducted in proper vessels heated by steam or water, with air-tight covers, means of carrying off offensive vapours, and safety-valves for the ready escape of gases suddenly produced. The removal of the finished matches from the frames, the making of them into packets, and the placing in boxes, all involve risks of ignition. The need of great caution in these operations is manifest, and vessels of water should always be close at hand.

The sanitary precautions required in this business are the provision of large, roomy workshops with good ventilation, assisted by fans or flues, and the exercise of extreme personal cleanliness, especially before partaking of food. The same clothing should not be worn at home as in the workshops. The hours of dangerous labour should be reduced to a minimum consistent with industrial economy. The inhalation of turpentine vapour, to favour oxidation of the phosphorus, and the washing out of the mouth with weak alkaline solution of carbonate of sodium or lime-water and charcoal are all to be recommended. As a substitute for turpentine, an aqueous solution of copper sulphate may be employed, as it precipitates the phosphorus as a phosphate along with metallic copper. Charcoal is of value as a powerful absorbent of phosphorus.

Fortunately, owing to an adequate recognition of the dangers attending the making of matches and other industries in which phosphorus is employed, poisoning by this element is by no means common now in this country.

The complete suppression of the use of white phosphorus is the surest preventive.

The notification of phosphorus poisoning by every medical practitioner attending on or called in to visit a patient suffering from this disease contracted in any factory or workshop, is now required by the Factory and Workshop Act, 1901, section 73.

Zinc is chiefly met with either as a carbonate (calamine), or as a sulphide (blende), or as a red oxide, the colour of which is due to mixture with oxides of iron and manganese. Zinc is not absorbed by the skin, and its effects are limited to absorption of its vapour by inhalation, or inhalation of the dust. Zinc vapours are largely given off during extraction of the metal from its ores, also during the preparation of "galvanised" iron sheets for roofing, of galvanic iron wire, and the preparation of alloys. Iron is "galvanised" either by dipping it into molten zinc, and covering with a layer of sal-ammoniac which dissolves the oxide which forms on the zinc; or by first coating the iron with tin, by galvanic action, and then dipping in molten zinc. Galvanic zincing is performed by placing the metal to be galvanised in a zinc bath filled with a saturated solution of sulphate of zinc. Brass and copper are sometimes zinced.

Zinc is much used as an alloy; thus, brass consists of equal parts of zinc and copper; and German silver is merely brass to which some nickel has been added. The inhalation of fumes arising during the casting of brass was known many years ago to produce a disease called brass-founders' ague. The injurious agent is the easily volatilised zinc oxide. Regulations prohibit the pouring of brass unless there be (*a*) an efficient exhaust for the removal of fumes at or near the point of origin; (*b*) efficient arrangements to prevent the fumes entering any room in which work is carried on; and (*c*) free openings in the upper part of the room. Females are not allowed to work in any process in which the pouring of brass is carried on. The maintenance of a lavatory supplied with warm water, soap, nail-brushes and so forth, is compulsory in all brass founderies. Zinc dust is created in larger quantities in the grinding of the oxide, and every precaution is needed to carry out this operation in suitable closed chambers, and to protect workmen by respirators. The proper condensation of all zinc vapour is imperative, combined with vigorous ventilation to free the workrooms from it.

The symptoms following exposure to the action of vapour of zinc are:—cough, difficulty of breathing, headache, giddiness, stiffness in the limbs, sickness, and vomiting. Excessive perspiration is not infrequent. The colic and itching of the skin which is frequently observed in persons exposed to zinc dust is often due to the action of impurities, especially of lead or of arsenic. Apart from this, however, zinc powder may mechanically cause irritation.

LAW RELATING TO TRADES, OFFENSIVE OR OTHERWISE.

OFFENSIVE TRADES.

In England and Wales.—The "offensive trades" are defined by section 112, Public Health Act, 1875, as those of "blood-boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, tripe-boiler, and any other noxious or offensive trade, business, or manufacture." By the same section it is illegal to establish any of these offensive trades within an urban sanitary district, without the consent in writing of the authority.

As regards the prohibition of the establishment of any given trade without

their consent, it is incumbent upon the prosecuting Local Authority to show that the trade in question is either one of those specifically mentioned above, or *ejusdem generis* with them; that is, that it is necessarily an offensive trade apart from neglect or mismanagement. It will be necessary, therefore, in determining whether a business comes within the definition of "offensive trade," to consider whether the materials used in its processes are identical with or similar to those dealt with in the six trades specified in the definition, and also whether the trade is, or must be, carried on in such manner as to be noxious or offensive. The higher Courts have held that this is the case with rag- and bone-stores for example, but not in brick-making, manure works, or fish-frying.

An urban Sanitary Authority may make bye-laws with respect to these trades, when they have been established with their consent, so as to prevent or diminish any nuisance arising therefrom (section 113); but a rural authority would have to apply to the Local Government Board for power, under section 276, to apply these provisions.

The Local Government Board have issued Model Bye-laws in regard to not only the six trades mentioned in section 112 of the Act of 1875, but also in reference to the trades of a leather-dresser, tanner, fat-melter or fat-extractor, glue-maker, size-maker, blood-drier, and gut-scraper. The same general provisions appear in all, with numerous additions or variations as required by the conditions of the particular trade in question. The following summary will show their general scope and character:—

(*a*) All materials not required for immediate use or treatment shall be so stored as to prevent effluvium. (*b*) The best practicable means must be adopted for rendering any offensive vapours emitted during melting, boiling, &c., innocuous. The vapour must be either discharged into the external air in such a manner and at such a height as to admit of its diffusion without injurious effects; or shall be passed directly from the pan, &c., through a fire; or into a condensing apparatus; or through a condensing apparatus and then through a fire; in such a manner as effectually to consume the vapour or deprive it of all noxious or injurious properties. (*c*) The drainage on the premises must be kept in efficient order. Bone-boilers must cool all hot liquid refuse before passing it into any drain. (*d*) Floors must be kept in good order so as to prevent the absorption of filth. In the majority of these trades it is advisable to require the floors to be either swept, washed, scraped, or otherwise cleansed at the close of every working day. All refuse so collected, by scraping or sweeping, shall be removed forthwith from the premises in covered receptacles, unless intended to be forthwith subjected to further trade processes on the premises. (*e*) Walls must be kept in good order so as to prevent the absorption of filth, and, if necessary, be scraped. Limewashing of walls and ceilings twice a year is necessary in regard to these trades. (*f*) All apparatus, including implements and vessels, must be kept clean; where possible, they should be cleaned daily. (*g*) Waste lime resulting from the businesses of fellmongers and tanners must be removed at once, and under close cover. (*h*) Tanks used by fellmongers for washing or soaking skins must be emptied and cleansed as often as may be necessary to prevent effluvia. (*i*) Every facility must be allowed for the access to the premises of the Medical Officer of Health, Inspector of Nuisances, Surveyor, or any Committee appointed by the authority, for the purpose of inspection at all reasonable times.

Section 114 enacts that, if the Medical Officer of Health, or two legally qualified medical practitioners, or ten inhabitants of a district, certify that any of the following places are a nuisance, or injurious to health, it is the duty of the Sanitary Authority to take proceedings against the offender, who is liable to a penalty not exceeding £5, nor less than 40*s*., unless he can show that he has used the best practical means for abating such nuisance, or preventing or counteracting such effluvia. The premises mentioned in this section are "any candle-house, melting-house, melting-place, or soap-house, or any slaughter-house, or any building or place for boiling offal or blood, or for boiling, burning, or crushing bones, or any manufactory, building, or place used for any trade, business, process, or manufacture causing effluvia." The same powers are applicable where a nuisance, affecting the inhabitants

of a district, arises from offensive trades carried on in premises situated beyond the limits of the district (section 115).

In London.—The provisions as to offensive trades under the Public Health (London) Act, 1891, are more stringent than the corresponding provisions of the Act of 1875 in force outside the metropolis. Section 19 of the London Act prohibits any one, under penalty of £50 per day or less, establishing within the metropolitan area the business of a blood-boiler, a bone-boiler, a manure manufacturer, a soap-boiler (if the soap is made from animal fats), a tallow-melter, or a knacker ; but old-established businesses of this kind are permitted to remain, subject to the bye-laws of the County Council. A new soap-boiling business may, however, be established with the sanction of the Council, provided the soap is made from olein, or any vegetable fat or oil (*ibid.* (2)). Certain other businesses may, with the consent of the County Council, be established anew ; these are those of a fellmonger, tripe-boiler, slaughterer of cattle or horses, or any other business which the Council may declare by order, confirmed by the Local Government Board, to be offensive. The expression " establishment anew " means re-opening after discontinuance of work for nine months, removal to new premises or extension of existing buildings, but not reconstruction, partial or complete, without extension of area. The granting of sanction to establish any new businesses of these kinds, on the part of the Council, is subject to the proviso that at least fourteen days before making any such order they notify to the authority, within whose district the premises on which the business is proposed to be established are situate, that application has been made, so that the inhabitants may have an opportunity of opposing it (section 19 (3)).

Sub-section (4) of the above-mentioned section enables the County Council to make bye-laws as to the arrangement of premises and conduct of such businesses. Any such bye-laws (5) may empower a Petty Sessional Court to prohibit any person from following the same temporarily or permanently subject to a daily penalty not exceeding £50 ; but any Sanitary Authority or person aggrieved by the enactment, alteration, or repeal of any such bye-law may give notice to the Local Government Board. The Metropolitan and Deptford cattle-markets are exempted from these bye-laws. Section 20 authorises the licensing of cow-houses and slaughter-houses, such licences being made annually. Section 22 of the Act provides that the removal, storage, and disposal of house and street refuse by a Sanitary Authority is to be deemed to be an offensive trade, and any complaint or proceeding made under section 21 may be made or taken by the County Council in like manner as if the Council were a Sanitary Authority. This provision enables the County Council to deal with a class of nuisance which is not infrequently alleged to be committed by Sanitary Authorities themselves in the discharge of their duties with respect to the removal and disposal of house and street refuse.

With these exceptions, the provisions of the London Act of 1891 as to offensive trades are practically the same as those of the Public Health Act, 1875, sections 114 and 115. In the City of London the Corporation take the place of the County Council for applying these enactments in connection with offensive trades.

In Scotland.—The Public Health (Scotland) Act, 1897, section 32, classifies as offensive trades " the business of a blood-boiler, bone-boiler, tanner, manure manufacturer, knacker, soap-boiler, skinner, tallow-melter, tripe-boiler, gut- or tripe-cleaner, skinner or hide-factor, slaughterer of cattle or horses, or any other business which the Local Authority may declare by order, confirmed by the Local Government Board, to be an offensive business.

The Local Authority may make bye-laws for regulating the conduct of any businesses within the meaning of the sections (32 and 37) of the Act and the structure of the premises in which any such businesses are being carried on in their district, in order to prevent or diminish the noxious or injurious effect thereof and the mode in which the application for sanction is to be made. Any business so conducted as to be offensive and injurious to health is deemed to be a statutory nuisance.

In the towns the Burghal Commissioners have power to pass bye-laws "for reducing or removing the noxious or injurious effects attending these offensive trades" (Burgh Police (Scotland) Act, 1892, section 316).

In Ireland.—Section 128 of the Irish Public Health Act of 1878 includes the business of a gut-manufacturer among the offensive trades, in addition to those given in section 112 of the English Act. As a rural Sanitary Authority in Ireland cannot be invested with urban powers, it follows that only urban authorities can prevent the establishment of an offensive trade within the meaning of the Public Health Act. The powers of these urban authorities to make bye-laws as to offensive trades is imperative in Ireland, and not permissive as in England, subject, of course, to the sanction of the Local Government Board of Ireland (Public Health (Ireland) Act, 1878, section 129). In other respects the provisions of the Irish and English Acts on this matter are similar.

ALKALI, CHEMICAL AND OTHER WORKS.

It has already been shown that the provisions of the Public Health Acts relating to what are called offensive trades apply only to a limited class of trades. Outside that class are a number of other trades, works, and businesses in which various noxious and offensive gases are evolved. These latter are placed under the inspection and regulation of officers of the Local Government Board, subject to the Alkali, &c., Works Regulation Act, 1906. This Act is to be regarded as cumulative, and nothing contained in it is to be construed as legalising any act or default which would otherwise be deemed to be a nuisance, or be contrary to law, had this not passed. Further, where it appears to any Sanitary Authority, on the written representation of their officers, or of any ten inhabitants of their district, that any work (either within or without their district) to which these Acts apply is carried on in contravention to them, or that any alkali waste is deposited (either within or without their district), and that a nuisance is occasioned by any such contravention of the Acts, such Sanitary Authority may complain to the Local Government Board, who, after inquiry, are empowered to direct such proceedings to be taken by an Inspector as they think just.

The following are the processes of manufacture which come under this Act of 1906, and are subject to inspection, registration and the payment of an annual fee for registration :—

(1) Alkali works, that is to say, every work for (*a*) the manufacture of sulphate of soda or sulphate of potash, or (*b*) the treatment of copper ores by common salt or other chlorides, whereby any sulphate is formed, in which muriatic acid gas is evolved. (2) Cement works. (3) Smelting works, that is to say, works in which sulphide ores, including regulars, are calcined or smelted. (4) Sulphuric acid works, that is to say, works in which the manufacture of sulphuric acid is carried on by the lead chamber process, namely, the process by which sulphurous acid is converted into sulphuric acid by the agency of oxides of nitrogen and by the use of a lead chamber. (5) Sulphuric acid works, that is to say, works in which the manufacture of sulphuric acid is carried on by any process other than the lead chamber process, and works for the concentration or distillation of sulphuric acid. (6) Chemical manure works, that is to say, works in which the manufacture of chemical manure is carried

on, and works in which any mineral phosphate is subjected to treatment involving chemical change through the application or use of any acid. (7) Gas liquor works, that is to say, works (not being sulphate of ammonia works or muriate of ammonia works) in which sulphuretted hydrogen or any other noxious or offensive gas is evolved by the use of ammoniacal liquor in any manufacturing process, and works in which any such liquor is desulphurised by the application of heat in any process connected with the purification of gas. (8) Nitric acid works, that is to say, works in which the manufacture of nitric acid is carried on, and works in which nitric acid is recovered from oxides of nitrogen. (9) Sulphate of ammonia works and muriate of ammonia works, that is to say, works in which the manufacture of sulphate of ammonia or of muriate of ammonia is carried on. (10) Chlorine works, that is to say, works in which chlorine is made or used in any manufacturing process. (11) Muriatic acid works, that is to say, (a) Muriatic acid works, or works (not being alkali works as defined in this Act) where muriatic acid gas is evolved either during the preparation of liquid muriatic acid or for use in any manufacturing process; (b) tin-plate flux works, that is to say, works in which any residue or flux from tin-plate works is calcined for the utilisation of such residue or flux, and in which muriatic acid gas is evolved; and (c) salt works, that is to say, works (not being works in which salt is produced by refining rock salt, otherwise than by the dissolution of rock salt at the place of deposit) in which the extraction of salt from brine is carried on, and in which muriatic acid gas is evolved. (12) Sulphide works, that is to say, works in which sulphuretted hydrogen is evolved by the decomposition of metallic sulphides, or in which sulphuretted hydrogen is used in the production of such sulphides. (13) Alkali waste works, that is to say, works in which alkali waste or the drainage therefrom is subjected to any chemical process for the recovery of sulphur or for the utilisation of any constituent of such waste or drainage. (14) Venetian red works, that is to say, works for the manufacture of Venetian red, crocus, or polishing powder, by heating sulphate or some other salt of iron. (15) Lead deposit works, that is to say, works in which the sulphate of lead deposit from sulphuric acid chambers is dried or smelted. (16) Arsenic works, that is to say, works for the preparation of arsenious acid, or where nitric acid or a nitrate is used in the manufacture of arsenic acid or an arseniate. (17) Nitrate and chloride of iron works, that is to say, works in which nitric acid or a nitrate is used in the manufacture of nitrate or chloride of iron. (18) Bisulphide of carbon works, that is to say, works for the manufacture of bisulphide of carbon. (19) Sulpho-cyanide works, that is to say, works in which the manufacture of any sulpho-cyanide is carried on by the reaction of bisulphide of carbon upon ammonia or any of its compounds. (20) Picric acid works, that is to say, works in which nitric acid or a nitrate is used in the manufacture of picric acid. (21) Paraffin oil works, that is to say, works in which crude shale oil is refined. (22) Bisulphite works, that is to say, works in which sulphurous acid is used in the manufacture of acid sulphites of the alkalis or alkaline earths. (23) Tar works, that is to say, works where gas-tar or coal-tar is distilled or is heated in any manufacturing process. (24) Zinc works, that is to say, works in which, by the application of heat, zinc is extracted from the ore, or from any residue containing that metal.

As regards sulphuric acid works, it may be added that by section 26 a period of three years from the commencement of the Act is allowed as regards the "over-heat pan process," before the full stringency of the Act is to apply.

It may also be useful to note that the expression "noxious or offensive gas" is defined as including the following gases and fumes :—Muriatic acid, sulphuric acid, sulphurous acid, except that arising solely from the combustion of coal, nitric acid and acid forming oxides of nitrogen, sulphuretted hydrogen, chlorine and its acid compounds, fluorine compounds, cyanogen compounds, bi-sulphide of carbon, chloride of sulphur, fumes from cement works, fumes containing copper, lead, antimony, arsenic, zinc, or their compounds, fumes from tar works.

Also it is provided that the expression "best practicable means," where used with respect to the prevention of the escape of noxious and offensive gases, has reference not only to the provision and the efficient maintenance of appliances adequate for preventing such escape, but also to the manner in which such appliances are used, and to the proper supervision, by the owner, of any operation in which such gases are evolved.

The following are the requirements of the Act of 1906 with respect to alkali works. Every such work must be carried on in such a manner that 95 per cent. of the hydrochloric acid gas evolved must be condensed, and not more than $\frac{1}{5}$th of a grain of hydrochloric acid gas per cubic foot of air, smoke, or chimney gases must escape from the works into the atmosphere.

Nor must there be more of the acid gases of sulphur and nitrogen than the equivalent of 4 grains of sulphuric anhydride per cubic foot of air. The owner of any alkali work which is carried on in contravention of these provisions is liable to a fine in the case of a first offence not exceeding £50, and in the case of every subsequent offence £100. Acid drainage must not be allowed to mix with alkali waste so as to cause a nuisance; the penalties for the contravention of this provision are similar to the above, with a continuing penalty of £5 a day. The owner may require the Sanitary Authority to provide and maintain, at his expense, a drain for carrying the acid waste into the sea, or any watercourse into which it can be taken without breach of the Rivers Pollution Prevention Act, 1876. Alkali waste must not be deposited or discharged without the best practicable and available means being used to prevent nuisance. Similar regulations apply to sulphuric acid works. The gases escaping into the atmosphere must not have an acidity equivalent to more than 4 grains of sulphuric anhydride per cubic foot. The other works scheduled in the Acts must employ the best practicable means for preventing the escape of noxious and offensive gases, and for rendering them harmless and inoffensive, subject to the qualification in the case of sulphuric acid works as to the degree of aerial vitiation by the escaping gases.

In calculating the proportion of acid to a cubic foot of air, smoke, or gases, for the purposes of the Act, such air, smoke, or gases are to be calculated at a temperature of 60° F. with a barometric pressure of 30 inches.

The Alkali Acts apply to Scotland, being locally administered by the public health authorities. The Secretary for Scotland is the central authority in place of the Local Government Board. The same Acts apply equally to Ireland, but the English Local Government Board has the appointing of the inspectors; while in all other respects the Irish Board is the central authority.

SLAUGHTER-HOUSES.

In England and Wales.—By section 4 of the Public Health Act, 1875, the expression "slaughter-house" includes the buildings and places commonly called slaughter-houses and knackers' yards, and any place or building used for slaughtering cattle, horses, or animals of any description for sale.

Section 169 of the Public Health Act, 1875, which incorporates certain provisions of the Towns Improvement Clauses Act, 1847, enacts that any urban Sanitary Authority may provide abattoirs or slaughter-houses, and if they do so, *must* make bye-laws with respect to their management and charges. They may also license slaughter-houses and knackers' yards, and without their licence no place shall be used for such purposes which was not so used at the time of the passing of the Act in 1875. Every place used as a slaughter-house or knackers' yard before the passing of the Act, and still continued to be so used, shall be registered by the owner or occupier in a book kept by the Sanitary Authority. The distinction, therefore, between a registered and licensed slaughter-house is dependent upon the fact that in the one case the place was used as such before the passing of the Act in 1875, while in the other case it has been established since that date. A legible notice bearing the words Licensed Slaughter-house or Registered Slaughter-house must be attached and displayed in some conspicuous place on every slaughter-house by the owner or occupier (section 170). Prior to the adoption of Part III. of the Public Health Acts Amendment Act, 1890,

in any district, licences granted under the above enactment will not be annual licences, but granted once for all; nor in those cases is a fresh licence necessary when part of the premises is rebuilt, or when any addition is made to them. The *continuance of use* is of great importance, as it is frequently found that slaughter-houses are disused as such, and applied to other purposes. In that case they cannot again be used as slaughter-houses without application for a licence. But in urban districts in which Part III. of the Act of 1890 is in force, licences, granted after the adoption of that Act, will be for not less than twelve months, or such periods as the licensing urban Sanitary Authority may deem fit to specify in it.

As regards slaughter-houses and other similar premises for which a licence is sought, the Local Government Board, in a Memorandum dated July 25, 1877, have suggested that the following rules as to site and structure should influence the decision of a Sanitary Authority before granting a licence :—

1. The premises . . . should not be within 100 feet of any dwelling-house; and the site should be such as to admit of free ventilation by direct communication with the external air on two sides at least of the slaughter-house.
2. Lairs for cattle in connection with the slaughter-house should not be within 100 feet of a dwelling-house.
3. The slaughter-house should not in any part be below the surface of the ground.
4. The approach to the slaughter-house should not be on an incline of more than one in four, and should not be through any dwelling-house or shop.
5. No room or loft should be constructed over the slaughter-house.
6. The slaughter-house should be provided with an adequate tank or other proper receptacle for water, so placed that the bottom shall not be less than 6 feet above the level of the floor of the slaughter-house.
7. The slaughter-house shall be provided with means of thorough ventilation.
8. The slaughter-house should be well paved with asphalte or concrete, and laid with proper slope and channel towards a gulley, which should be properly trapped and covered with a grating, the bars of which should not be more than ⅜ths of an inch apart. Provision for the effectual drainage of the slaughter-house should also be made.
9. The surface of the walls in the interior of the slaughter-house should be covered with hard, smooth, impervious material to a sufficient height.
10. No water-closet, privy, or cesspool should be constructed within the slaughter-house. There should be no direct communication between the slaughter-house and any stable, water-closet, privy, or cesspool.
11. Every lair for cattle in connection with the slaughter-house should be properly paved, drained, and ventilated. No habitable room should be constructed over any lair.

It is the duty of the Sanitary Authority to make bye-laws for the licensing, registering, and inspection of slaughter-houses and knackers' yards, and preventing cruelty therein, for keeping the same clean, for the daily removal of filth, and for the proper supply of water. The following Model Bye-laws, issued by the Local Government Board, are applicable to the above requirements :—

(*a*) *Licences.*—Applications for licence of existing premises, or erection of new slaughter-houses, must be made upon a specified form, and must include full particulars as to the position, form, area, cubic space, &c., of the buildings and appendages; materials and construction of walls and floors; means of water-supply, drainage, lighting, and ventilation means of access for cattle; number, position, and size of stalls or lairs, and number of animals to be accommodated therein, distinguishing oxen, calves, sheep, and swine. The boundaries must also be shown, and, in the case of old premises, particulars as to the ownership and the applicant's tenure must be given.

(*b*) *Registration.*—If the Sanitary Authority approve the application, a licence shall be issued to the applicant, and must be registered by him at the office of the Sanitary Authority.

(*c*) *Inspection.*—Free access to every slaughter-house for the purpose of Inspection must be afforded at all reasonable times to the Medical Officer of Health, Inspector, Surveyor, and Committees appointed by the Sanitary Authority.

(*d*) *Water* must be supplied to every animal kept in a lair prior to slaughter.

(*e*) *Mode of Slaughter.*—Cattle must be secured by the head so as to be felled with as little pain as practicable.

(*f*) *Drainage, water-supply, and ventilation* must be kept in efficient order.

(*g*) *Cleanliness.*—The walls and floor must be kept in good order and repair, and must

be thoroughly cleansed within three hours after any slaughtering; the walls and ceiling must be limewashed four times yearly, that is to say, within the first ten days of March, June, September, and December respectively.

(*h*) *Animals not to be kept.*—No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting or otherwise.

(*i*) *Removal of Refuse.*—Suitable vessels made of non-absorbent materials, and provided with close-fitting covers, must be provided for the reception of blood, manure, garbage, and other refuse. All such matters must be placed in these vessels immediately after the slaughtering. The refuse must be removed within twenty-four hours, and the vessels forthwith cleansed. All skins, fat, and offal must be removed within twenty-four hours.

If any person is convicted of killing or dressing any cattle contrary to the provisions of the Public Health Act, or of the non-observance of any of the bye-laws or regulations made under the Act, the justices before whom he is convicted may suspend the licence for two months or less, and in the event of a second offence may revoke the licence (Towns Improvement Clauses Act, 1847, sections 125 to 130, incorporated in section 169 of the Public Health Act, 1875). A similar revocation of licence may follow on conviction for sale of meat unfit for food (Public Health Acts Amendment Act, 1890, section 31).

In London, by section 20 of the Public Health (London) Act, 1891, it is provided that a person carrying on the business of a slaughterer of cattle or of horses, knacker or dairyman, may not use any premises in London (outside the city) as a slaughter-house without a licence from the County Council. In the city, the licensing authority is the City Corporation. The section does not extend to slaughter-houses erected in the Metropolitan Cattle Market, under the authority of the Metropolitan Market Act, 1851, or the similar Act of 1857. The general provisions as to slaughter-houses are the same as in the provinces, particularly when read in conjunction with section 47 relating to the sale of unsound food. Conviction under this section entails cancellation of licence.

In Scotland.—The Public Health (Scotland) Act, 1897, does not specially deal with slaughter-houses, but the business of a "slaughterer of cattle or horses" is included under offensive trades, and is practically subject to the regulations which govern them both in burghs and landward districts (section 32).

Under section 33, a person carrying on the business of a slaughterer of cattle or horses or knacker shall not use any premises as a slaughter-house or knacker's yard without a licence from the Local Authority, under a penalty not exceeding £5, and the fact that cattle or horses have been taken into unlicensed premises shall be *primâ facie* evidence that an offence has been committed.

In the burghs, the Commissioners have full control over the slaughter-houses, and none can be used without their licence; moreover, if they provide premises of this kind, no others may be used (Burgh Police (Scotland) Act, 1892, sections 278 to 287).

In Ireland, the provisions of the Public Health Act are practically the same as those in force in England. In towns constituted under the Towns Improvement (Ireland) Act, 1854, if section 47 of that Act has been adopted, the provisions of the Towns Clauses Act, 1847, incorporated into the Public Health (Ireland) Act by virtue of section 105, with regard to slaughter-houses, will be in force although such towns may not be urban sanitary districts; and the Town Commissioners "may by special order purchase, rent, build, or otherwise provide such slaughter-houses and knackers' yards as they think proper for slaughtering cattle within the town."

FACTORIES AND WORKSHOPS.

The sanitary legislation in respect of these places is somewhat complicated. A reference to page 27 will show that section 91 of the Public Health Act, 1875, includes as a nuisance any factory, workshop, or workplace not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as possible any gases, vapours, dust, or other impurities generated in the course of the work carried on therein; * or so overcrowded while work is carried on as to be dangerous or injurious to the health of those employed therein. These provisions, however, do not apply to a factory which is subject to the provisions of the Factory and Workshop Act of 1901. This Act is in force in England and Wales, the Metropolis, Scotland, and Ireland, consequently references as to its working under the special headings of these geographical areas is not necessary.

The general effect of the Factory and Workshop Act is to place all factories and workshops under a dual control, namely, the Home Office and the various District Councils. The Home Secretary appoints Factory Inspectors, whose primary duty is to inspect *factories*. On the other hand, the primary duty of inspecting *workshops* and workplaces rests with the Local Authorities; this statement, however, must not be interpreted as meaning that the District Councils have no right to inspect a factory under the operation of this Act, for there is a general duty cast upon the Local Authorities to inspect all parts of their districts.

By the Factory and Workshop Act, 1901, *factories* include (1) all places in which mechanical power is used in aid of the manufacturing process; and (2) the following, whether power be used or not:—print-works, bleaching and dye-works, earthenware works, lucifer-match works, percussion-cap works, cartridge works, paper-staining works, fustian-cutting works, blast-furnaces, copper mills, iron mills, foundries, metal and india-rubber works, paper mills, glass-works, tobacco factories, letterpress printing works, book-binding works, flax scutch mills, electrical stations.

A "*tenement factory*" is one in which mechanical power is supplied to different parts of the same building occupied by different persons, for the purpose of any manufacturing process or handicraft in such manner that these parts constitute in law separate factories.

Workshops include (1) the following, unless they are factories by reason of the use of mechanical power:—hat-works, rope-works, bake-houses (any places in which are baked bread, biscuits, or confectionery from the baking or selling of which a profit is derived), lace warehouses, ship-building yards, quarries, pit-banks of metalliferous mines, dry-cleaning works, carpet-beating works, and bottle-washing works; (2) premises (not being factories) in which manual labour is exercised by way of trade or for purposes of gain, in or incidental to the making, altering, repairing, ornamenting, finishing or adapting for sale of any article, if the employer has the right of access or control; (3) tenement workshops; that is, workplaces in which, "with the permission of or under agreement with the owner or occupier, two or more persons carry on any work which would constitute the workplace a workshop if the persons working therein were in the employment of the owner or occupier." Instances of tenement workshops are the Sheffield file-cutting shops, where file-cutters work on their own account; also journey-

* In this connection the following may be consulted: *Illustrations of Methods of Dust Extraction*, by Commander Sir H. P. Freer-Smith, R.N., London, 1906. Published under authority of Home Office.

men tailors' workshops where men hire a separate sitting or place to work from the owner or occupier.

Domestic factories and *domestic workshops* are those carried on in private houses, without use of mechanical power, where the only persons employed are members of the same family dwelling there. If any work certified by the Home Secretary to be dangerous is carried on, they are treated as ordinary factories and workshops; otherwise they are, so far as sanitation is concerned, treated as ordinary workshops, except that the requirements as to general ventilation and drainage of floors do not apply. The following, if carried on under conditions which would otherwise make the premises a domestic workshop, are exempted:—(1) Straw-plaiting, pillow-lace making, glove-making; (2) work done at irregular intervals, and not furnishing the principal means of living to the family.

Men's workshops (those in which only males over eighteen are employed) are exempted from several of the provisions of the Act, including those relating to general ventilation, temperature, drainage of floors, sanitary accommodation, lavatories, fans for removal of dust or fumes, and means of escape from fire.

Crown factories and workshops are excluded from the jurisdiction of the Sanitary Authority.

Workplace is not defined, but has a wider meaning than workshop, and has been held to include any place where people assemble together to do work permanently, *e.g.*, a stable and stable-yard, where men are employed as cab-cleaners and horse-keepers.

In factories, sanitation generally is enforced by the Factory Inspector, not by the District Council, hereafter referred to as the Sanitary Authority, but the latter deals with the means of escape from fire (in London this rests with the County Council), and have special duties in connection with bake-houses and domestic factories, as well as with sanitary accommodation under section 9 of the Factory Act, 1901, also under section 38 of the Public Health Act, 1875, and where Part III. of the Public Health Acts (Amendment) Act, 1890, is in force, under section 22 of that Act. If any act or default, punishable or remediable under the Public Health Acts, but not under the Factory Act, is found by the Factory Inspector in a factory or workshop, he is to report it to the Sanitary Authority, who must make inquiry, take such action as may seem proper, and inform the Factory Inspector what has been done. If proceedings are not taken by the Sanitary Authority within a month, the Factory Inspector may institute proceedings in default, and recover from the Sanitary Authority any expenses not recovered from other persons, and not incurred in unsuccessful proceedings (section 5). If the Sanitary Authority fail generally to carry out their duties with regard to factories, workshops, or workplaces, the Home Secretary may authorise the Factory Inspector to act in default for a specified period, and the expenses not recovered from other persons may be recovered from the Sanitary Authority.

In workshops and workplaces the Sanitary Authority (sections 2, 3, 4 and 5) is primarily responsible for enforcing sanitary requirements generally, and means of escape from fire; and their officers have the same powers of entry, inspection, and legal proceedings as Inspectors of Factories. Certain sanitary requirements, however, more particularly those relating to temperature, fans for removal of dust and fumes, and those arising under the Factory Act (as distinguished from the powers of the Sanitary Authority under the Public Health Acts) with regard to sanitary accommodation are enforced by the Factory Inspectors. The Sanitary Authority is required

to keep a register of all workshops in its district (section 131). If the Medical Officer of Health finds any woman, young person, or child employed in a workshop in which no abstract of the Factory Act is affixed, he is required to inform the Factory Inspector. The occupier of a new factory, workshop or laundry must notify the Factory Inspector, who, in the case of a workshop, forwards the notice to the Sanitary Authority.

The Medical Officer (under section 132) is required in his annual report to report specifically upon the administration with regard to workshops and workplaces, and to send a copy to the Home Secretary. A table issued by the Local Government Board, for the guidance of the Medical Officer of Health, includes the items calling for statistical record.

Outside the Factory Act, the Sanitary Authority is concerned with certain factories and workshops on public health grounds, as sources of smoke, poisonous fumes, trade effluents; as places where offensive trades or food manufacture needing control are carried on; as new buildings needing approval of plans, or old buildings in a dangerous state; or more indirectly as places in which infection may be spread from one person to another, or (as in laundries) infected articles may be handled. Nor are these the only points claiming the attention of the various officials of the Sanitary Authority in connection with plans for new factories and workshops. Others are strength of foundations and structure generally where heavy machinery is to be fixed; means of escape from fire; sanitary accommodation. Others, again, are the statutory requirements as to air space, ventilation and warming; the surfaces of walls and ceilings must be such as to admit of due cleansing, and the proper construction of floors (soundness, impermeability, slope, drainage) is of importance in certain processes. In certain dangerous trades additional structural requirements arise, and in some the plans have also to be approved by the Chief Inspector of Factories.

The requirements of the Factory and Workshop Act, 1901, in the above-mentioned matters, and which it is the duty of the Sanitary Authority to enforce, are as follows:—

Cleanliness.—By section 2 every workshop and workplace must be kept in a cleanly state, and if not so kept may be dealt with as a nuisance under the Public Health Acts. A workshop or any specified part thereof (in London this power extends to domestic factories and to workplaces, Public Health (London) Act, 1891, section 25) must be limewashed, cleansed or purified when so required, by notice from the Sanitary Authority, on the certificate of the medical officer or Sanitary Inspector that it is necessary for the health of the workers. All factories must be kept in a cleanly state, and (subject to certain exceptions) either (*a*) limewashed every fourteen months, or (*b*) painted with oil or varnished every seven years, and washed with soap and hot water every fourteen months. For the cleaning of floors, &c., damp processes are preferable, as checking the production of dust.

Air Space.—Factories, workshops and workplaces (sections 2 and 3) must not be so overcrowded as to be dangerous or injurious to the health of the workers, and there must be at least 250 cubic feet of air space for each worker; during overtime for women 400 cubic feet must be provided, 500 cubic feet in underground bakehouses, 400 cubic feet between 9 P.M. and 6 A.M. in other bakehouses with light other than electric, 400 cubic feet in workshops (not domestic) used also as sleeping-rooms. The air space of each workroom must be stated in a notice affixed in the works. A much larger air space is required in certain dangerous trades, and in works where certain special exceptions are permitted, *e.g.*, in match factories in which

yellow phosphorus is used the minimum is 400 cubic feet, and height above 14 feet is not counted, and in engineering works exemption from routine annual limewashing is allowed if the air space be 2500 cubic feet per head.

General Ventilation (section 7) must be efficient in every workroom of a factory or workshop (other than a men's workshop), and any standard fixed by the Home Secretary must be observed; thus, a limit of 9 volumes of carbon dioxide per 10,000 of air in humid cotton-cloth factories is required, and 600 cubic feet of fresh air per head per hour must be supplied in other humid textile factories. Air samples are taken usually at the breathing-level, at points when work is carried on, and not in extreme corners or near to inlets or outlets, or close to persons or to sources of carbon dioxide. In breweries, aerated water factories, bakehouses, &c., where carbonic acid is given off by trade processes, allowance has to be made; and similarly where artificial lighting yields carbon dioxide. As a rule, it is well to make a parallel determination in the open air. Mechanical ventilation by fans may be either on the plenum or the vacuum system. The number, position, dimensions and speed of the fans are matters requiring expert knowledge; as a rule, better results are obtained by large fans moving slowly than by small fans at a high speed. Plenum is, on the whole, preferable, and offers facilities for warming, screening or moistening the air when necessary. Exhaust ventilation calls for care in guarding against indraught through closets or other unsuitable channels. Paddle fans, which churn the air without changing it, are not to be regarded as means of ventilation, though the currents they cause may promote evaporation, and thus have some cooling effect. If reliance is placed on natural ventilation (whether by chimneys, open windows and doors, ventilators or shafts), supervision becomes necessary, especially in cold weather. In any case, care should be taken to secure ventilation of all parts of the room, to avoid short-circuiting and direct draughts upon workers, and to provide adequately for both inlets and outlets (sections 2 and 7).

Local Ventilation, for removal of dust, gases, vapours, or other impurities generated in the course of work, which are a nuisance or injurious to health, must be such as to render them harmless as far as possible. Usually this involves exhaust ventilation, applied at or near the point of origin; and fans (or other efficient mechanical means) for the purpose are prescribed in certain dangerous processes, and can be required by the Factory Inspector in others. Exhaust ventilation may sometimes be secured by connection with flues or other heated shafts, but in general fans are required, and need careful planning. The essentials are that the dust or fumes should be intercepted as near as possible to their source, and carried away from the workers, without entering the general air of the room; that the draught should be adequate for the purpose, and guided where necessary by hoods; and that the air-ducts should be kept clean and discharge at a suitable point, preferably in a closed dust-chamber. As a rule, a downward draught is best, since it carries away the dust more readily. The efficiency of exhaust can be tested by anemometers or by smoke, light dust, or fumes of ammonium chloride. In some instances, standards are fixed, in terms of sectional area of openings and velocity at given points. Other measures are the use of closed chambers or boxes, and as regards dust the adoption of wet processes, handling the dusty materials over gratings through which the dust can fall, cleanliness of premises and floors, and the use of overalls.

As a last resource respirators may be adopted, especially where the occupation is intermittent, but there is difficulty in enforcing the systematic use of them, and most of them entail some physical discomfort if worn for

long periods or in heavy work. The essentials in a respirator are that it should be light, simple, inexpensive, the filtering material readily renewed or cleaned; that it should not be unsightly; that it should arrest all dust, filter the inspired air, and prevent the re-breathing of expired air; and that it should offer the minimum resistance to the free passage of air without respiratory effort, and without becoming obstructed in use by moisture from the breath. A fold of cambric covering the mouth and nostrils is an efficient, simple respirator. Many elaborate forms fail when tried under the actual conditions of the work for which they are proposed. Some kinds of dust are directly infective, thus anthrax, tetanus, small-pox (among rag-sorters in paper-works and elsewhere); others are poisonous (*e.g.*, lead, mercury); and others, again, are mechanically injurious in varying degree. Similarly the wide variety of gases, fumes and vapours, which arise in manufacturing processes, and require removal, include many which are directly poisonous (*e.g.*, carbon monoxide, carbon bisulphide, sulphuretted hydrogen, sulphurous acid, chlorine, nitrous and other acid fumes, arseniuretted hydrogen; lead, zinc, and mercury fumes), and some which are harmful in other ways (for instance, steam), or offensive (organic effluvia). Explosion may arise from ignition of inflammable dust or fumes mixed with air; thus ordinary gas, marsh gas (in coal mines), naphtha, coal dust, or celluloid borings.

Temperature.—In every workroom of a factory or workshop provision must be made for securing a reasonable temperature (section 6), and without interfering with the purity of the air of the room. This requirement is enforced by the Factory Inspector. Gas-jets cannot be accepted as means of warming, nor must the ventilators be closed. As a lower limit 60° F. is suitable for sedentary occupations, but active work can be carried on at a lower temperature. The upper limit is not easily defined, since in certain processes a high temperature is a trade necessity, while in others it is only accidental. In humid cotton-cloth factories it is forbidden to raise the temperature artificially above 70° F., except so far as is necessary for moistening the air. If the air be dry, high temperatures can be borne, but as a rule where work is hard, high wet-bulb temperatures should be avoided. Humidity is expressly regulated in textile factories generally, such as spinning- and weaving-sheds where the air is moistened by steam jets or otherwise to facilitate the efficient working and treatment of the cotton fibres. In these places a limit of humidity is fixed for each dry-bulb degree, thus, 88 per cent. from 59° to 70° F., decreasing thence to 77·5 per cent. at 80° F., 69 per cent. at 90° F., and 64 per cent. at 100° F. In certain textile processes, however, a difference of 2° between wet and dry bulbs is accepted at all temperatures. Hygrometers must be affixed in each room, and (except in cotton-spinning mills), records kept of two (in cotton-cloth factories three) daily readings at 7 to 8 A.M., 10 to 11 A.M. and 3 to 4 P.M. The water used for humidification must be taken either from a pure source or be effectively purified; a water which gives off an offensive smell on being heated, or which absorbs more than 0·5 mgm. of oxygen from an acid solution of potassium permanganate in two hours at 60° F. is to be regarded as unsuitable. Owing to the clothing of workers becoming damp in moist air warmed ventilated cloak-rooms are obligatory in newly built, humid cotton-weaving sheds.

By section 8 of the Factory Act, 1901, it is required that in every workshop or part of a workshop in which any process is carried on which renders the floor liable to be wet to such an extent that the wet is capable of being removed by drainage, adequate means must be provided for draining off the wet. A workshop, not so drained, may be dealt with as a nuisance under

the Public Health Acts. This provision does not apply to workshops used only by men.

Sanitary Accommodation.—In London and where section 22 of Part III., Public Health (Amendment) Act, 1890, is in force, Sanitary Authorities can enforce the provision of suitable and sufficient sanitary accommodation in workshops or factories. Elsewhere, the Sanitary Authority has power under section 38 of the Public Health Act, 1875, in respect of the same matter; but section 9 of the Factory Act, 1901, is still more explicit, and lays down that the Secretary of State shall, by special order, determine what is sufficient accommodation within the meaning of this section. The following are the instructions given by an Order, made under this section 9, on February 4, 1903:—

1. In factories or workshops where females are employed or in attendance there shall be one sanitary convenience for every twenty-five females.

In factories or workshops where males are employed or in attendance there shall be one sanitary convenience for every twenty-five males; provided that (*a*) in factories or workshops where the number of males employed or in attendance exceeds one hundred, and sufficient urinal accommodation is also provided, it shall be sufficient if there is one sanitary convenience for every twenty-five males up to the first hundred and one for every forty after; (*b*) in factories or workshops where the number of males employed or in attendance exceeds five hundred, and the district Inspector of Factories certifies in writing that by means of a check system, or otherwise, proper supervision or control in regard to the use of the conveniences are exercised by officers specially appointed for that purpose, it shall be sufficient if one sanitary convenience is provided for every sixty males, in addition to sufficient urinal accommodation. Any certificate given by an Inspector shall be kept attached to the general register, and shall be liable at any time to be revoked by notice in writing from the Inspector. In calculating the number of conveniences required by this Order, any odd number of persons less than twenty-five, forty, or sixty, as the case may be, shall be reckoned as twenty-five, forty, or sixty.

2. Every sanitary convenience shall be kept in a cleanly state, shall be sufficiently ventilated and lighted, and shall not communicate with any workroom except through the open air or through an intervening ventilated space; provided that in workrooms in use prior to January 1, 1903, and mechanically ventilated in such manner that air cannot be drawn into the workroom through the sanitary convenience, an intervening ventilated space shall not be required.

3. Every sanitary convenience shall be under cover and so partitioned off as to secure privacy, and if for the use of females, shall have a proper door and fastenings.

4. The sanitary conveniences in a factory or workshop shall be so arranged and maintained as to be conveniently accessible to all persons employed therein at all times during their employment.

5. Where persons of both sexes are employed, the conveniences for each sex shall be so placed or so screened that the interior shall not be visible, even when the door of any convenience is open, from any place where persons of the other sex have to work or to pass; and, if the conveniences for one sex adjoin those for the other sex, the approaches shall be separate.

Safety from Fire.—By sections 14 and 15 it is the duty of a District Council, and in London the duty of the County Council, to see that every factory and workshop in its district is provided with sufficient means of escape in case of fire. Factories built after 1891 and workshops built after 1895 must, if more than forty persons are employed, have a certificate from the Sanitary Authority as to reasonable adequacy in this respect, specifying in detail the means provided. In older works with more than forty persons employed, the Sanitary Authority must see that reasonable provision is made, and if not, must require the owner by notice to carry out specified details in a given time; any dispute to be settled by arbitration. The whole of a tenement factory or tenement workshop is counted as one. Subject to confirmation by the Local Government Board, the Sanitary Authority may make bye-laws as to means of escape from fire in any factories or workshops.

Home Work.—Very important powers of controlling the conditions under which certain classes of work are done in the homes of the workers are

given to Sanitary Authorities by sections 107 to 115 of the Factory Act, 1901. These powers aim at the prevention of home work being done (1) in dwellings which are injurious or dangerous to the health of the workers themselves; (2) in premises where there is infectious disease. The employer must keep lists of the names and addresses of the out-workers, and send copies to the Sanitary Authority of his district on or before February 1 and August 1 of each year, in a prescribed form. If any such addresses are outside the area of the authority, particulars of them must be sent by the Sanitary Authority to the authority concerned. If the home premises are injurious or dangerous (overcrowding, want of ventilation, or other insanitary condition) to the health of the workers, the Sanitary Authority may prohibit the employer giving out the work to be done there. This power may be exercised also in the case of work given out from places other than factories or workshops, as, for instance, shops, warehouses or laundries. The power does not apply to all classes of home work, but only to those which may be specified by Orders of the Home Secretary. By virtue of Order No. 939, dated August 15, 1905, the power is applied to the following classes of work :—the making, cleaning, washing, altering, ornamenting, finishing and repairing of wearing apparel, and any work incidental thereto; the making, ornamenting, mending and finishing of lace, and of lace curtains and nets; cabinet and furniture making and upholstery work; the making of electro-plate; the making of files; fur-pulling; the making of iron and steel cables and chains; the making of iron and steel anchors and grapnels; the making of cart-gear, including swivels, rings, loops, gear-buckles, mullin-bits, hooks, and attachments of all kinds; the making of locks, latches and keys; the making of covers for and finishing of umbrellas, sunshades, parasols; the making of paper bags and paper boxes; brush-making, and the making of stuffed toys.

If an inmate of the house is suffering from a notifiable infectious disease (no matter if removed), the Sanitary Authority may, by Order, prohibit the employer from giving out work to be done in that home, or in any specified part of it, during a specified period. This power applies only to the following businesses, as laid down in the Order No. 939, of the Home Secretary :—the making, cleaning, washing, altering, ornamenting, finishing and repairing of wearing apparel, and any work incidental thereto; the making, ornamenting, mending and finishing of lace, and of lace curtains and nets; upholstery work and fur-pulling; the making of covers for the finishing of umbrellas, sunshades and parasols; the making of paper bags and paper boxes; brush-making and the making of stuffed toys.

In cases of emergency, the power to prohibit the issue of work to infected houses may be exercised by any two members of the Sanitary Authority, on the advice of the Medical Officer of Health, and the order may be subject to conditions as to disinfection or other precautions. In cases of small-pox or scarlet fever, an employer giving out work or wearing apparel is subject to penalty, irrespective of any order from the Sanitary Authority, unless he can prove that he was unaware of the illness.

The bearing of this Factory and Workshop Act, 1901, upon *bakehouses* has been explained on page 311, but it is noteworthy that *laundries* also come within the range of this Act. They are not technically factories or workshops, but, as regards sanitation, are subject to the same requirements. In addition to the ordinary sanitary requirements as laid down for factories and workshops, in factory laundries (*a*) fans are required for regulating the temperature of ironing-rooms, and for removing steam from wash-houses; (*b*) stoves for heating irons must be sufficiently separated from the ironing-room, and gas-irons emitting noxious fumes must not be used; (*c*) floors

must be kept in good condition, and so drained as to allow the water to flow off freely. Laundries in which the only persons employed are (*a*) inmates of a prison, reformatory, industrial school or other institution subject to inspection under any other Act; or (*b*) inmates of a religious or charitable institution; or (*c*) members of the same family dwelling there, or in which not more than two persons dwelling elsewhere are employed, are exempted (section 103).

Among other provisions of the Factory Act, bearing upon the well-being of the worker, may be mentioned those relating to safety from machinery, accidents, age and sex of those employed, and the hours and intervals for work and rest. Children under twelve years of age may not be employed in factories or workshops. Above twelve, they may be employed for half-time (if they have attained a certain standard, and if the local educational bye-laws permit), but must attend school for the other half. In factories they must have a certificate of fitness (as to age and physique) from the certifying surgeon, which may be coupled with conditions as to the nature of the employment allowed. "Young persons" are those between fourteen and eighteen (or between thirteen and fourteen, subject to conditions as to educational certificates), and are eligible for full-time employment, with certain limitations. Certificates of fitness are required for those under sixteen employed in factories. A woman must not be employed within four weeks after giving birth to a child.

The period of employment for women and young persons in textile factories is, on ordinary days, 12 hours (6 to 6 or 7 to 7), less 2 hours' intervals, and on Saturday 6 hours (6 to 12 or 7 to 1, with half-hour interval, or 6 to 12.30, with an hour interval); or a weekly total of 55½ working hours. In non-textile factories and in workshops, it is 12 hours on ordinary days (6 to 6, 7 to 7, or 8 to 8), with 1½ hour intervals, and on Saturdays, 8 hours (6 to 2, 7 to 3, or 8 to 4), with half-hour interval; or a weekly total of 60 hours. In laundries the period must not exceed 14 hours for women, 12 hours for young persons, or 10 hours for children in any consecutive 24 hours; or a weekly total of 60 hours for women and young persons, and 30 hours for children. There is a further limit as to continuous spell of employment, which must not exceed 4½ hours in textile factories and printing, bleaching and dyeing works, or 5 hours in non-textile factories, workshops and laundries, without an interval of half an hour. Certain holidays, amounting to six days in the year, are prescribed. Work on Sundays is prohibited. The hours, intervals and holidays must be fixed by notice. None of the above provisions apply to men over eighteen, and certain exceptions are allowed as regards women, young persons and children in special cases; thus, women may be employed overtime for 2 hours, on not more than three days in any week, nor more than thirty days in any twelve months, in certain specified branches; and in others male young persons can be employed at night.

CHAPTER XV

PARASITES

In its widest sense, the name of parasites has been given to those creatures which are nourished wholly or partially at the expense of other living organisms. As thus understood, parasitic life is, therefore, an exceedingly widespread phenomenon, and includes not only vegetable and animal parasites, but also parasites on vegetables and on animals. The length of parasitic existence, and the degree and nature of the benefit which the parasite thus obtains, vary greatly with different species; and the effect produced by the parasite upon its host ranges from an almost imperceptible one to complete destruction. At one extreme are certain forms which, while drawing the nourishment necessary for life from their hosts, yet do so in such fashion that both organisms continue to live in intimate association, and apparently with mutual advantage. From these we can pass, by a series of gradations, to parasites of such destructive influence as to cause widespread death to certain animal and vegetable forms of life. This physiological and pathological group is closely related to the saprophytes, which obtain their nourishment from the dead remains of organisms.

From the foregoing necessarily abbreviated statement we observe not only the enormously wide prevalence of parasitism, but its very considerable variety in degree and detail. The majority of parasites, indeed, derive their main support from their host, but of these some are free, wandering about from animal to animal, some are attached permanently to the exterior of their victim, while others again are concealed within its body. In some cases, the parasitism is only temporary, in others it is a life-long habit. The majority are free in their youth, while some pass their early life as parasites, becoming free in their mature state, and others again spend their whole life on their host.

Some classification of these various parasitic forms is necessary. Van Beneden introduced the term *commensals* or messmates, including fixed and free partners, as distinguished from true parasites. In this classification there is no attempt to define the degree of dependence or the closeness of association, except in the general distinction between parasites and messmates. Leuckart distinguishes parasites as ecto- and endo-parasites, and divides the former into temporary and permanent. Endo-parasites he divides according to the nature and duration of their strictly parasitic life :—(1) Some having free-living and self-supporting embryos, which become sexually mature either in their freedom, or only after assuming the parasitic habit. (2) Others with embryos which, without having a strictly free life, yet pass through a period of active or passive wandering, living for a while in an intermediate host. They may either (*a*) escape to pass their adult life in freedom; or (*b*) they may become sexual; or (*c*) they may bore their way to another part of the body; or (*d*) most frequently they pass to their final host either directly when their intermediate host is devoured as food, or indirectly seek for themselves another intermediate host, or produce asexual

forms which do so. (3) Others, again, having no free-living or even migratory embryonic stage, but passing through their complete life-cycle in one host. This somewhat detailed classification has at least the advantage of clearness, and of showing to some extent the various degrees of parasitism; but it is confined, like Beneden's, entirely to animals living as parasites upon other animals, and fails to include those vegetable forms which inhabit a living organism and obtain nourishment from its body.

A more physiological classification has been proposed by Kossmann, dealing with the organisation and habit of the parasite. Any strict classification of such a variety of organisms as the parasites, having only in common the physiological correspondence of their mode of life, is almost impossible, and the most that can be done is to point out the existence of a series of adaptations varying with the intimacy and constancy of the association, and the degree of dependence.

The parasites of man cover a wide range in the animal and vegetable world, and embrace species from such diverse organisms as the Schizomycetes, the Blastomycetes, the Hyphomycetes, the Protozoa, the Platyhelminthes, the Nematodes, the Acanthocephala, the Hirudinea and the Arthropoda. Of these, the parasitic bacteria or Schizomycetes will not be included in this article, as their importance in morbid processes, and particularly in the infective diseases, is such as to require separate and special treatment. Some further reference to them will be found in the chapter which discusses the infective diseases.

BLASTOMYCETES, OR YEASTS.

A familiar example of this group is *torula*, which is capable of producing alcohol when growing in substances containing glucose. By torula is understood an oval micro-organism, varying in size from 3 to 6 μ, and consisting of a membrane and protoplasmic contents, including often one or two vacuoles. A characteristic feature of these organisms is that they multiply by budding and not by fission. A very large number of different species of torulas have been described, especially in connection with alcoholic fermentation. These organisms are of interest to the hygienist in two ways:—(1) by their constantly being present in the air, soil, and water; and (2) by a species of torula being connected with a well-defined disease known as *thrush* in infants.

Oïdium albicans, or the active cause of thrush, is a torula morphologically identical with the species connected with alcoholic fermentation. Upon saccharine cultures, poor in water and cut off from the air, this torula grows like yeast and excites fermentation. Upon nutrient media, rich in nitrogen and water, it forms articulated filaments, longer or shorter, which in many places support rounded or oval conidia. Upon gelatin plates, it develops as coarsely granulated growths, reminding one of yeast colonies; it does not liquefy the gelatin. It is pathogenic for poultry and pigeons on inoculation in the crop, where it develops a characteristic aphthous membrane.

HYPHOMYCETES, OR MOULDS.

This group comprises organisms "which consist of cells multiplying by fission, and which, by continued linear and lateral multiplication and by elongation, form branched mycelial threads; each of these is composed of

cylindrical cells." The actual mature cells consist of a faintly granular protoplasm contained in a cellular sheath. The ripe cells are separated from one another by transverse septa; these, however, are not present in the young cells.

In some species of this group, the terminal threads, by a simple process of fission, produce free cells which are conidia or spores. These species are known as oïdium, the chief being oïdium lactis, the oïdium of favus, the oïdium of ringworm and of pityriasis versicolor. The spores, by germination, elongate, grow, divide, and ultimately give rise to a branched mycelium of cylindrical cells. Other species, like Aspergillus, Mucor, and Penicillium, under favourable conditions with free exposure to the air, present a more complicated mode of spore formation; but when unfavourably situated they behave like an oïdium, forming spores by simple fission of the terminal cells of the filamentous threads.

Oïdium lactis is often an abundant inhabitant of sour milk, bread, paste, potato, and gelatin. It is said to have no pathogenic properties. It appears as a whitish filamentous growth, with spherical or oval spores measuring 7 to 10 μ.

Achorion schönleini is the oïdium of favus, and like that of ringworm (*Trichophyton tonsurans*), and of pityriasis versicolor (*Microsporon furfur*), closely resembles, both in its cultural and morphological characters, the oïdium lactis. Upon serum, it forms elliptical conidia without special supporters. Upon gelatin, it grows slowly with gradual liquefaction, first as a whitish, flocky layer, and then thick, dry, and white. It grows also on agar and potato. The *Trichophyton tonsurans* is very like the above, but the filaments are more rectilinear. It only grows at an incubation temperature and on an alkaline medium. It liquefies gelatin, grows on agar and serum, but not on potato.

Aspergillus.—The various forms of Aspergillus are only observed saprophytically in man, especially in the lungs, external auditory meatus, and middle ear. The spores, introduced into the vascular system of animals, establish metastatic foci in the various viscera. To this group also belong Saprolegnia, Botrytis Bassiana, and possibly Actinomyces or the ray fungus.

Saprolegnia are colourless threads, forming dense radiating tufts, which occur on living and dead animal and vegetable matter in fresh water. The filaments penetrate into the substratum, and branch more or less in the surrounding water. This parasite attacks fish and tritons, producing a diseased condition of the skin, which may be ultimately fatal. It produces the common disease of salmon.

Botrytis bassiana.—This occurs as colourless hyphæ and spores, the former being usually simple, but sometimes united in arborescent stems. This fungus is the cause of muscardine, a fatal disease of silk-worms, and occurs also in various other caterpillars and insects.

Streptothrix.—Saprophytic streptotricheæ are widely distributed in nature, while parasitic species, whether pathogenic or not, have also a wide range of existence. Some are parasites on grasses and the root nodules of the leguminosæ; others are found infesting oysters, lizards and fowls. Among species infecting higher animals are *Streptothrix bovis*, sometimes called actinomyces or the ray fungus, found in cattle, camels and horses; *S. nocardii*, causing disease in oxen; *S. capræ*, found in the goat; together with other species described as occurring in pigs, dogs, rabbits and other mammalia. With the exception of *S. bovis*, none of the species infecting lower animals have been found to be the cause of disease in man, but certain varieties which have been isolated from man resemble some of the sapro-

phytic species common in air, water and soil. Other well-known forms of the streptotricheæ affecting man are *S. maduræ*, the cause of Madura foot; *S. eppingeri*, found in an abscess; and *S. hominis*, found by Foulerton * in a case of pyonephritis. Morphologically and culturally, a streptothrix shows first a tangled mass of mycelium with lateral branches, which later show segmentation and chain sporulation until at last the culture shows only spores arranged in irregular masses like staphylococci and streptococci. In their late stage the component parts of this mould stain by Gram, but not in the early mycelial stage. In man and animals, streptothrix infection usually gives rise to only local tumour or abscess. The frequency of primary infection in the mouth and air passages and among those working with grain or herbage, suggests the air or food as the medium of infection, and also the cerealia as the normal habitat of the parasite.

PROTOZOA.

Along with the vegetable parasites above described and the larger animal intruders, to be discussed subsequently, we have in the course of years become acquainted with a series of small animal organisms which throughout their entire life never rise above the unicellular stage, or merely form simple colonies of similar unicellular creatures; these are grouped under the term *protozoa* and are probably the simplest types of animal life. Some instances of these organisms, parasitic to man, are:—

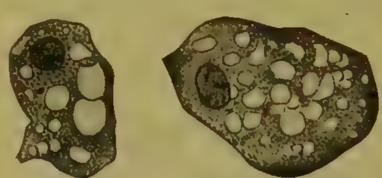


FIG. 93.—AMŒBA DYSENTERIÆ *vel* HISTOLYTICA.

Amœba dysenteriæ.—Various observers, notably Lösch, Kartulis, and Councilman, have described round or slightly oblong bodies, consisting of an outer pale homogeneous substance enclosing a somewhat greenish, highly refractive mass, containing vacuoles and a nucleus, as being present in certain forms of dysentery. Their size varies from 0·008 to 0·05 mm. A characteristic feature of these amœba-like bodies is movement, consisting first of a progressive movement, and secondly of a protrusion and withdrawal of pseudopodia, both of which vary in activity. Entering probably with the food, these protozoa pass on until the large intestine is reached, where the alkalinity necessary to their growth is obtained. Here they penetrate and undermine the mucous membrane, producing their effects by liquefying the tissues, and thus causing ulceration and necrosis. In the mucous membrane they are found chiefly in the lymph spaces, blood-vessels, and in the gelatinous contents of the ulcers. They may penetrate to the liver (Fig. 93). Although the experimental infection produced in animals to prove the pathogenic nature of the amœbæ of the intestine is not above criticism, still the general opinion is that a direct causal connection exists between certain forms of dysentery and the protozoon here mentioned. Satisfactory pure growths of amœbæ from the intestine of man have not been obtained, and recent work points to the impossibility of such a procedure, because a complementary symbiotic living organism is indispensable for the nourishment of these protozoa; but Musgrave and Clegg † have shown clearly that the possibility of cultivating amœbæ on artificial media is quite possible. Other species

* Foulerton: "On Streptothrix Infections," *Lancet*, 1899, vol. ii. p. 779; also *Lancet*, 1906, vol. i. p. 970.

† Musgrave and Clegg: Bull. No. 18, Bureau of Govern. Laboratory, Manila, 1904.

of amœba have been described, from time to time, as occurring in the tissues and fluids of the human body, but the statements are probably based on faulty observations.

Trichomonas vaginalis.—This flagellated protozoon has a pyriform body, the anterior part being rounded and the posterior part pointed; attached usually to the front extremity are three or four long flagella, while in addition there is an undulating membrane that commences at the anterior extremity and proceeds obliquely backwards. Its length varies from 0·015 to 0·02 mm. and the breadth between 0·008 to 0·012 mm. Three trichomonades have been described as inhabiting human beings:—one, *T. vaginalis*, lives in the acid vaginal mucus of women of various ages and has also been found in the urethra of man; another, *T. intestinalis*, has been noted in the bowel contents; and a third, *T. pulmonalis*, has been observed in the lungs. (Fig. 94.) It is probable that these are all the same, and that *Trichomonas vaginalis* finds the conditions necessary to its existence in various organs of man that are accessible from the outside. Experimental transmission to mammals by the mouth has proved negative, but it is probable that either air or water, possibly both, are the vehicles. The only pathological state associated with the presence of trichomonades in man has been diarrhœa.

Fig. 94.—Trichomonas vaginalis (after Künstler).

Lamblia intestinalis.—This parasite inhabits the small intestine of various mammals, such as dogs, cats, rats, mice, sheep, and man. Encysted forms are found in the colon. It is a pear-shaped protozoon 0·02 mm. long and 0·01 broad, with a hollow on the front part of the inferior surface. It has four pairs of flagella directed backwards, of which three pairs lie on the borders of the hollow, and the fourth arises from the pointed posterior extremity. (Fig. 95.) The presence of free forms in the bowel causes some increased peristalsis, but it is doubtful whether this parasite is associated with any pathological condition. Infection occurs by ingesting the encysted forms. Cereals, or food prepared from cereals, polluted with *Lamblia* by animals living in the vicinity of human dwellings, such as rats and mice, are probably the vehicles by which they are introduced into man.

Fig. 95.—Front and Side Views of Lamblia intestinalis (after Grassi).

Cercomonas hominis. — Typical cercomonades have been observed in the intestine of man by a number of workers. These flagellates are elliptical or fusiform and rarely pear-shaped; they are provided with a flagellum at one end, while the other extremity terminates usually in a long point. (Fig. 96.) As with Trichomonas vaginalis, so with Cercomonas hominis, it would appear that the parasite settles not only in the intestine but also in the air passages; other species have been noted in the urine; these have shown two flagella. The average length of the cercomonades

found in man is 0·01 mm., the flagellum being twice as long as the body.

Trypanosoma.—This species of protozoa is characterised by the possession of a longitudinal undulating membrane, the thickened border of which takes its origin posteriorly from a mass of chromatin or centrosome, and terminates anteriorly in a free flagellum. Stained specimens show a large nucleus, usually about the middle of the body. Division takes place longitudinally. The trypanosomidæ occur in fish, amphibia, reptiles, birds, and mammals. Most of these are very incompletely known, and it is only recently that a few forms have acquired great importance from the fact that they cause more or less serious disease in both man and domestic animals. (Plate X.) We may enumerate the following species :—

T. rotatorium, found in the blood of frogs ; it is 40 to 80 μ long and 5 to 10 μ broad. The flagellum is some 12 μ long, and the body surface longitudinally striated.

T. carassii, found in the blood of tench, pike and sticklebacks. Besides the forms having an undulating membrane and flagellum, certain disc-like shapes have been described.

T. cobitis. This is 40 μ long and 2 μ broad, found in the blood of the mud-fish. It is long and thin, and forms without flagellum and undulating membrane have been described. A similar parasite has been found in the blood of the sole.

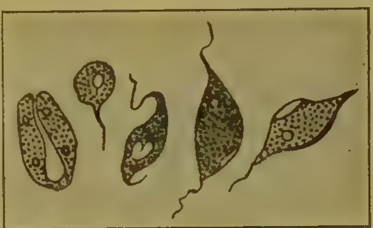


Fig. 96.—Cercomonas hominis (after Lambl).

T. sanguinis was first found by T. Lewis in the blood of rats. It measures 30 μ by 3 μ and is apparently non-pathogenic ; it is common in rats of tropical countries, infection being said to be transmitted from rat to rat by means of the rat-flea.

T. evansi is the parasite of surra, a febrile disease of horses, mules, and camels prevalent in many parts of India. Rogers states that the disease in India is conveyed by a species of *tabanus* or horsefly, while Manders gives, for Mauritius, Stomoxys calcitrans as the probable vehicular host. In size this parasite resembles that of the rat, but its movements are perhaps more active.

T. equinum measures 22 μ by 3 μ and is the parasite causing a disease of horses in Central and South America, called Mal de Caderas. Horned cattle appear to be refractory. It is thought that the infection is transmitted by a biting fly (Stomoxys calcitrans).

T. equiperdum. This trypanosome is the cause of the disease among horses in Algeria known as *dourine*. It measures 20 μ by 2 μ and is conveyed, as far as is known, under natural conditions by coitus only, and not by means of flies. The animals become anæmic, paraplegia sets in, and death follows in a few months. In asses, the symptoms are much slighter. Ruminants appear to be refractory to infection by this parasite.

T. brucei. This is the highly pathogenic trypanosome of *ngana* or tsetse-fly disease. Its size is 27 μ by 2 μ. This parasite appears to be fatal to all mammals, and was shown by Bruce to be conveyed from infected animals to healthy ones by means of tsetse flies, the fly, after biting, remaining infective from twelve to forty-eight hours. There is some morphological resemblance between T. brucei and T. evansi and T. equinum. *T. brucei* is shorter and more compact than *T. evansi*, the movements, too, being less extensive, also its protoplasm has larger and more numerous granules. One of the most striking morphological distinctions between

T. brucei and *T. equinum* is the difference in the size of their centrosomes. In *T. equinum* it is so small that some have denied its existence. That ngana and surra are not identical diseases is best proved by the fact that an animal immunised against the former is yet susceptible to inoculation with the latter; similarly, animals immunised against *T. equinum* and *T. equiperdum* succumb to inoculation with *T. brucei.* The value and reliability of these differential immunisation experiments has been challenged by Koch.

T. ugandiense. This is the notorious parasite found in the cerebro-spinal fluid of cases of sleeping-sickness, so prevalent in Uganda, on the Congo and in other parts of Central and West Africa. Its size averages 22 μ by 2 μ. There is some reason to regard this trypanosome as but a variety of that discovered by Dutton in the blood of a European in the Gambia; the morphological differences are trivial and chiefly refer to the centrosome, which in the Uganda specimens is nearer the extremity and outside the vacuole; at the same time *T. ugandiense* has a more rounded posterior extremity than *T. gambiense.* The distribution of the *T. ugandiense* is tolerably extensive and appears to be identical with that of a biting fly (*Glossina palpalis*), which was shown by Bruce to be the means of conveying the infection to both man and monkeys. The species known as *T. grayi* and *T. tullochii*, found occasionally in Glossina palpalis, appear to have nothing to do with sleeping-sickness and are not developmental forms of *T. gambiense*, as once supposed.*

T. theileri is another trypanosome found in the blood of cattle in the Transvaal, subject to a disease known as "gall sickness." It is very long and narrow, measuring from 30 to 70 μ by from 2 to 4 μ. Theiler has shown that a biting fly (*Hippobosca rufipes*) transmits the disease from oxen to oxen.

T. transvaaliense represents another flagellated protozoon found in the blood of oxen in the Transvaal. It is from 18 to 50 μ long by from 4 to 6 μ broad. Its centrosome almost touches the nucleus, and the undulating membrane is consequently little developed. Among other trypanosomes which have been noted may be mentioned one found in camels in Somaliland, and one causing horse disease in Gambia. This latter is referred to under the name of *T. dimorphon* and is some 24 μ long by 3 μ in breadth. Very few details are known at present regarding either its morphology or history.

The life history of the trypanosomes is imperfectly known, but, with one exception, all the species which have been investigated have a second host, which is an invertebrate of some kind. The exception is *T. equiperdum* of dourine, which is said to be transmitted direct from a sick animal to a healthy one by means of coitus. The intermediate host in all the other cases is a blood-sucking invertebrate, and in this host alone does the sexual cycle take place.

Trypanosomes can be distinguished, more or less easily, into three forms, namely, indifferent forms, and so-called male and female forms. All three types may multiply by fission, but in the male and female individuals this function may be in abeyance. In the blood of vertebrates, all three forms can be more or less recognised, but the full differentiation only occurs in the invertebrate host. In either host, the sexual types appear to be recruited by differentiation of indifferent forms into males and females. The males are slender, with a long flagellum, and the cytoplasm is clear. The females are broader and less active. In them the nucleus is round and compact, while the cytoplasm is full of coarse granules. The males are the more

* Minchin, Gray and Tulloch: "Glossina palpalis in Relation to T. Gambiense," *Journ. Roy. Army Med. Corps*, vol. vii. p. 568.

PLATE X.

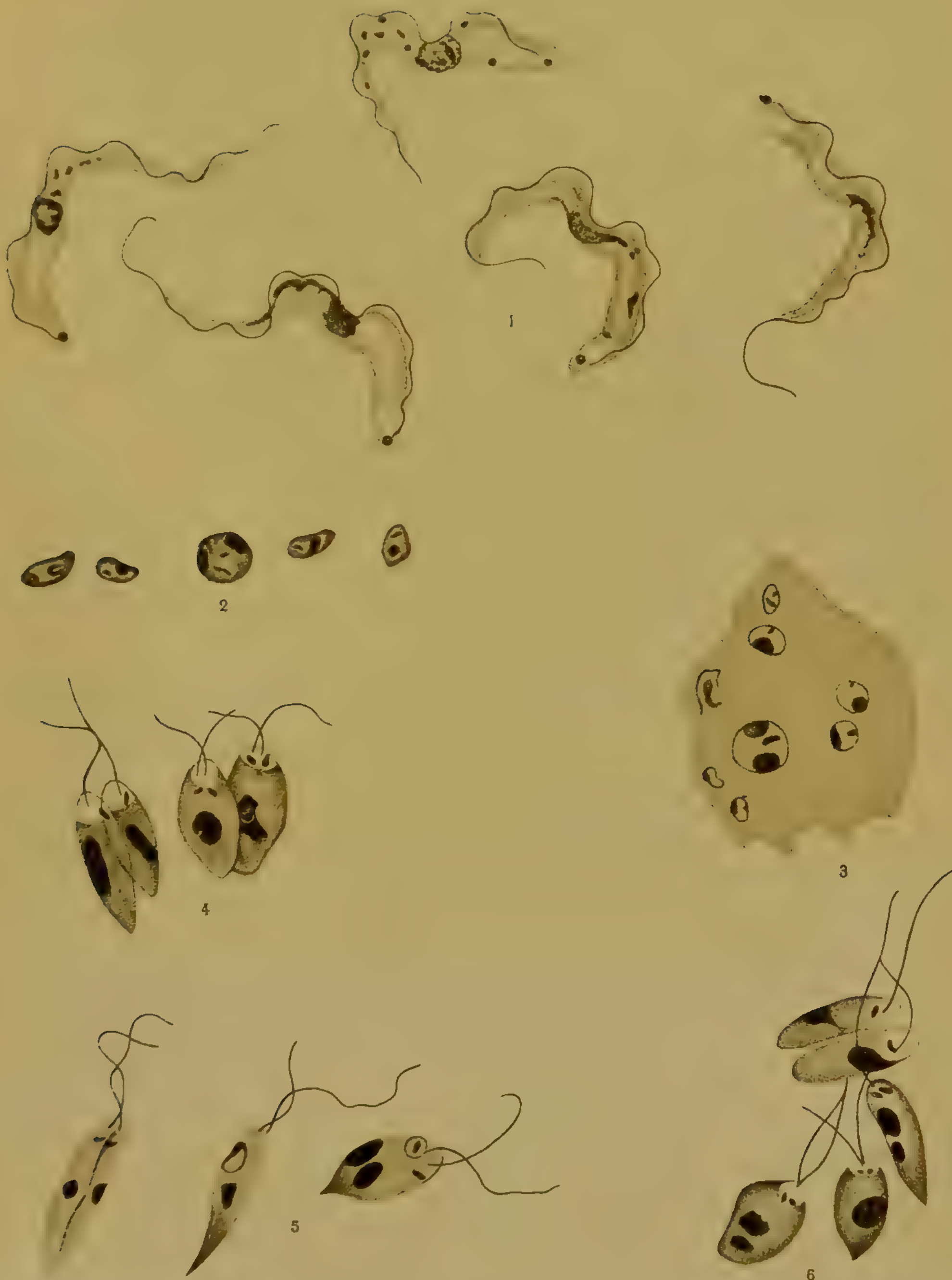


Fig. 1 Trypanosomes Fig. 2 Free forms of Leishmania donovani

Fig. 3 Intracellular forms of Leishmania donovani

Figs. 4, 5 and 6 Flagellated developmental forms of L. donovani

delicate, and the females the more resistant to adverse conditions. Under certain conditions, the females are capable of self-fertilisation and revert to the indifferent type. This then multiplies by longitudinal fission and so repopulates its host, its descendants being again differentiated later on into males and females. Before conjugation, the sexual forms mature by elimination of the nuclear substance. The maturation may occur in a vertebrate host, but in that case is abortive; usually it occurs in the invertebrate host, where alone conjugation can take place. During conjugation, the flagella and undulating membrane disappear, while the single blepharoblast produced by the fission passes into the single nucleus of like origin. The result is a gregarine-like form, in which the nucleus undergoes heteropolar division, a flagellum and undulating membrane form and the zygote becomes an ordinary trypanosome. These sexual changes occur only in the invertebrate host. Numerous other forms and phases of trypanosomes are known, but these are considered to be merely degenerated types and quite unlike the phases of the natural cycle. If the work of Schaudinn on the life-cycle of the trypanosome of the little stone owl (Athene noctua) can be confirmed, we have in that observation a clue to the bionomics of all the mastigophora. According to Schaudinn, the *T. noctuæ* ensures the continuity of its existence by an alternation of generative processes and by a change of hosts, its intermediary host being the little stone owl, and its definitive host the mosquito, *Culex pipiens*.

Recently, Salvin-Moore and Breinl,* working with T. gambiense, have questioned the occurrence of sexual dimorphism. They describe, during certain stages of trypanosomiasis, the occurrence of a spore-like resistant body in which the macro-nucleus alone remains surrounded by a clear space. Subsequently, in this resistant form of a trypanosome the micro-nucleus originates from the macro-nucleus, and from this there grows out a flagellum; further, in the consequent division there is a process which is analogous to the separation of two kinds of nuclei destined to conjugate. A pair of such differentiated nuclei is retained in each trypanosome; these unite and produce by fission young trypanosomes. The view of these observers is, that the union of the macro- and micro-nuclei may correspond to a sexual act, so that, in the parasite of sleeping-sickness we have a life-cycle which appears to be complete within the body of one animal.

It is obvious that much has still to be learnt regarding this interesting and pathologically important species of the protozoa. Roughly speaking, the trypanosomidæ can be divided into two groups, the first comprising trypanosomes of fishes, reptiles, rats, and Theiler's disease in cattle; the other embraces the parasites of ngana, surra, Mal de Caderas, and sleeping-sickness. The first group is distinguished by the constancy of the virulence, morphology and behaviour of its members towards their hosts; rat trypanosomes can only be cultivated successfully in rats, and Theiler's trypanosome only in cattle. These features suggest that these parasites have for long been confined exclusively to their present hosts and thus acquired constant characters, and become clearly defined species. On the other hand, the behaviour of the trypanosomes of the second group indicates no exclusive confinement to a definite host, no constancy in either morphology or virulence, and consequently suggests that they have been living but a comparatively short time in their hosts, have not become fully adapted to them, and are not developed yet into distinct species. Regarded from this point of view, we are disposed to think that, in spite of minor morphological

* Salvin-Moore and Breinl: "On the Life-cycle of the Parasite of Sleeping-sickness," *Lancet*, 1907, vol. i. p. 1219.

differences, it will be shown ultimately that the parasites of Mal de Caderas, tsetse disease and surra are one and the same, so too will be probably the recognition of unity in causative agency of the various types of trypanosomiasis in man. It is impossible to dogmatise at present, but such seems to us to be the direction in which precise knowledge will lead.

Spirochæta.—This genus appears to be allied closely to the trypanosomidæ, and some important parasitic forms have been referred to it. These micro-organisms have the appearance of minute slender threads, wavy or spirally twisted in form. They have often been confused with bacteria of the genus *spirillum*, but they differ from a true spirillum in having the flexible body enveloped only in a soft periblast and not in a cuticular or firm cell-membrane; moreover, they possess an undulating membrane, but no flagellum. The true type of this genus is the *S. plicatilis*, which has an undulating membrane, no trace of flagella, a blunt round-ended body and a nuclear apparatus of a thread-like structure. Among the more important organisms said to be included in this genus are:—*S. ziemanni*, occurring in the blood of the owl, Athene noctua; *S. obermeieri* of relapsing fever in man; *S. duttoni* of human tick fever;* *Treponema pallidum* of syphilis; and *S. pertenuis* of yaws. (Fig. 97.)

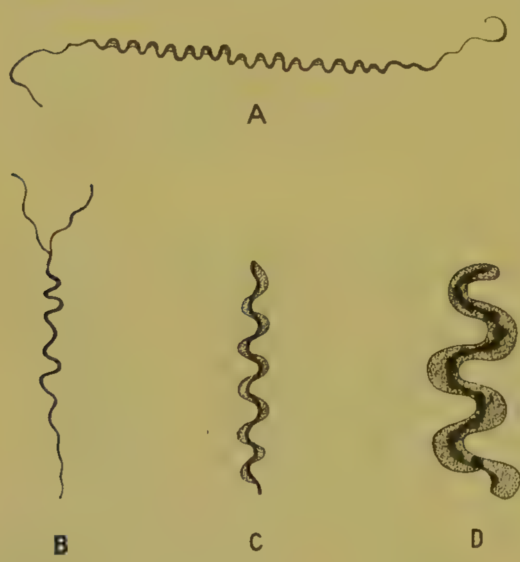


Fig. 97.—**A** and **B**, Treponema pallidum. **C**, Spirochæta refringens. **D**, Spirochæta plicatilis.

Our knowledge of S. ziemanni is derived mainly from the work of Schaudinn, from which we infer that these organisms are in reality minute trypanosomes and, as such, not belonging to this genus at all. As regards the Spirochætes of relapsing fever and human tick fever, it is an open question whether these forms, and others occurring in fowls and geese, ought not to be referred to the bacteria and not to the protozoa. The true spirochæta multiply by longitudinal division, and have an undulating membrane; according to Koch † and Zettnow,‡ there is no undulating membrane in either S. obermeieri or S. duttoni, and further, both forms multiply by transverse fission. Prowazek § maintains the exact converse. In the face of these contradictory statements, we can only leave the question as open for decision by further research. Like other blood-parasites, the hæmatozoic spirochæta are transmitted to new hosts by blood-sucking invertebrates. Thus, S. obermeieri is conveyed by the bed-bug; S. duttoni by the tick, *Ornithodoros moubata;* S. gallinarum is conveyed by fowl-ticks of the genus *Argus;* and S. ziemanni by the mosquito *Culex pipiens*. Novy and Knapp || are of opinion that these various organisms belong to the bacteria and not to the protozoa.

* Breinl: "On the Specific Nature of the Spirochæta of African Tick Fever," *Lancet*, 1906, vol. i. p. 1690.

† Koch: "Uber Afrikanische Recurrens," *Berlin Klin. Wochsch.*, February 12, 1906, p. 185.

‡ Zettnow: "Färbung u. Theilung bei Spirochæten," *Zeitsch. f. Hygiene*, 1906, lii. p. 485.

§ Prowazek: "Morpholog. u. Entwickelun. Untersuch. u. Hühnersspirochæten," *Archiv. f. Protistenkunde*, 1906, xxiii. p. 554.

|| Novy and Knapp: "Studies on Sp. Obermeieri and Related Organisms," *Journal of Inf. Diseases*, 1906, vol. iii. p. 291.

Treponema pallidum, which is now recognised generally to be the causative agent of syphilis and *S. pertenuis*, found in yaws, differ somewhat from typical spirochæta in that they have a corkscrew-like body, with numerous sharp coils, which vary from fifteen to twenty-five in number and are retained when the organism is at rest, whereas with all other spirilla the spirals more or less disappear when the organism is motionless. Another feature of these species is the apparent possession of an undulating membrane and a slender flagellum at each of the tapering ends of the body. These minute organisms are very active and constantly rotate on their principal axis. They possess a low refractive index and are difficult to detect. In deeply seated syphilitic lesions, Treponema pallidum occurs alone, but in ulcerated surfaces is associated with another species, distinguished by a greater refractivity and visibility, but by fewer twists to its body. This is *S. refringens* of Schaudinn.* At present little is known of the spirochæta of yaws. The apparent absence of any intermediate host and the transmission of Treponema pallidum by coitus is a suggestive analogy to the case of Trypanosoma equiperdum in dourine. The characteristics of the spirochæta have been well summarised by Maclennan.†

Leishmania.—Under this heading we refer to certain human parasites which have been and are still the subject of some controversy. These are the so-called Leishman-Donovan bodies found in the spleen and other organs in Kala-azar, also those generally referred to as the parasites of oriental sore. The precise biological position of these organisms is undetermined, but our present knowledge warrants the employment of the generic name *Leishmania* as a sub-order of the flagellated protozoa and represented by two known species, namely, *L. donovani*, or the parasite of Kala-azar, and *L. tropica*, which is the parasite of oriental sore.‡

The Leishmania occurring in human tissues are minute, rounded, ovoid or pyriform bodies measuring from 2 to 3 μ in their longer diameter, and 1·5 to 2 μ across the shorter axis. The cytoplasm is often vacuolated and contains two chromatin masses or nuclei usually situated on the shorter axis of the body. (Plate X.) The larger one is compact and stains faintly, the smaller nucleus is rod-like and stains deeply. The parasites multiply either by simple binary division or by multiple fission in which both nuclei share. These organisms are typically intracellular, being found in leucocytes and cells of endothelial nature; occasionally free forms are found. Practically nothing is known of *L. tropica*, but Rogers,§ Leishman,‖ and Christophers¶ have shown that, when cultivated in suitable media and at moderate temperature, the *L. donovani* undergo changes which result in their becoming flagellate organisms, somewhat suggestive of *herpetomonas*. Nothing is known of the natural development of these parasites outside the human body, though it is suspected that that of oriental sore may be disseminated by some insect attracted by open sores or wounds. Some form of arthropod has been suggested as the intermediary for the Kala-azar organism, more

* Schaudinn: "Zur Kentniss der Spirochæte pallida," *Deutsch. Med. Wochsch.*, No. 42, October 19, 1905.

† Maclennan: "On the Spirochæta pallida and its Variations," *Brit. Med. Journal*, 1906, vol. i. p. 1090.

‡ Wright, J. H.: "Protozoa in a Case of Tropical Ulcer," *Journal of Med. Research*, 1903, No. X., p. 472.

§ Rogers: "On the Development of Flagellated Organisms from Protozoic Parasites of Kala-azar," *Proc. Roy. Soc.*, No. 77, p. 284.

‖ Leishman and Statham: "The Development of the Leishman Body in Cultivation," *Journ. Roy. Army Med. Corps*, 1905, vol. iv. p. 321; see also *idem.*, vol. iv. p. 13.

¶ Christophers: "On a Parasite found in Persons suffering from Enlarged Spleen in India," *Sci. Mem. Med. Officers of Army of India*, Nos. 8, 11, and 15.

particularly the Indian bed-bug, Cimex rotundatus, but before this can be affirmed several gaps need to be filled. It is not unlikely that there exists some minute spirillar stage which is ultra-microscopic.

Recently, Patton * has shown that a herpetomonas of Culex pipiens and a species of crithidia of the water-bug have a stage in their life-cycles in which they are similar in form to the Leishman-Donovan bodies, and, further, that the former multiplies in a similar manner to the human parasite. In order to study the early stages of these parasites it is necessary to examine the hind- and mid-guts of the larvæ and nymphs of these insects. There is at present no evidence of a sexual cycle or of the infection being inherited.

Among the class Sporozoa of the protozoa, several important parasites of man are to be found; these for the most part belong to the orders *coccidiidea* and *hæmosporidia*.

Coccidium hominis.—This is probably the same species as inhabits the intestinal epithelial cells of rabbits and described as *C. cuniculi*. The infection of man by this parasite is associated with serious symptoms, such as fever, diarrhœa, and enlarged liver, which after death is found to be invaded by caseous centres surrounded by inflamed areas with numerous coccidia in the hepatic cells as well as in the epithelium of the biliary ducts. The number of actual and well-authenticated cases in man is, however, small,

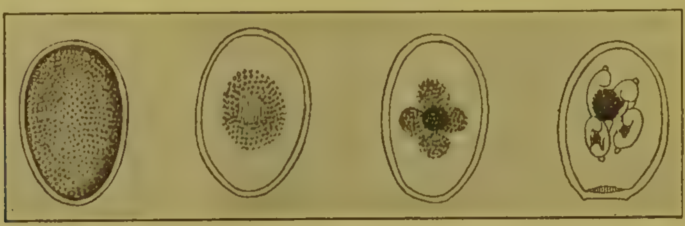
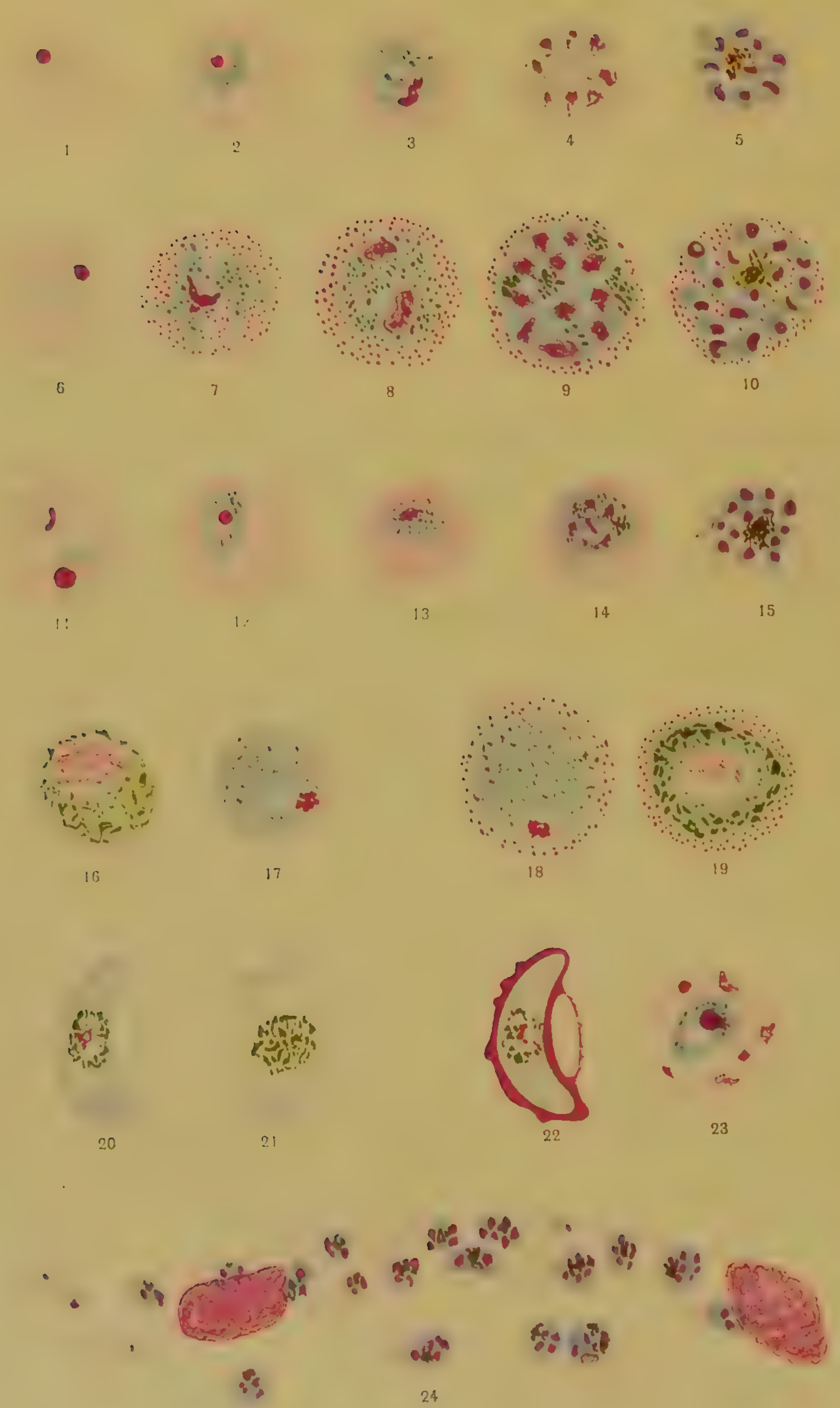


FIG. 98.—COCCIDIUM HOMINIS (AFTER RIEK).

though the distribution of coccidial infection among the lower animals is comparatively extensive. The life-cycle of this parasite is a somewhat complicated process, in that two manners of development occur alternately. The Coccidia, in their mature condition, live usually in the epithelial cells of various organs, but prefer those of the intestine and its dependent viscera. Their size varies, but rarely attains 1 mm.; in form they are globular, oval, or elliptical, the body substance being finely granulated protoplasm with no differentiation into ecto- and endo-sac. (Fig. 98.) The infected epithelial cell degenerates as the parasite feeds on it, until finally its cellular membrane alone surrounds the coccidium, which is now a schizont. Schizogony now commences, culminating in the formation of a number of sickle-shaped forms called merozoits, which soon gain their freedom. The merozoits do not gain the open in the usual way, but further infect the same host by penetrating other epithelial cells of the affected organ; here they continue their growth and may undergo schizogony over and over again. In course of time, this schizogony ceases and the merozoits that have penetrated epithelial cells differentiate into two types, one having a light protoplasm, the other an opaque and granular body substance. These are respectively male and female gametes and, ultimately, fructification of the female gamete follows, which now becomes an encysted sporont. Possibly by this time the encysted sporont may have been discharged from its host's body,

* Patton: "Note on the Life-cycle of a Species of Herpetomonas found in Culex pipiens," *Brit. Med. Journal*, 1907, vol. ii. p. 78.

PLATE XI



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Figs. 1-5—Parasites of Quartan Malaria
Figs. 6-10—Parasites of Benign Tertian Malaria
Figs. 11-15—Parasites of Malignant Tertian Malaria
Figs. 16-17—Gametocytes of Quartan Malaria. No. 16, male parasite: No. 17, female parasite
Figs. 18-19—Gametocytes of Benign Tertian Malaria. No. 18, macrogamete; No. 19, microgametocyte
Figs. 20-22—Gametocytes of Malignant Tertian Malaria. Nos. 20 and 22, macrogametes: No. 21, microgametocyte
Fig. 23—Young Malignant Tertian Parasite, showing Maurer's dots
Fig. 24—Smear preparation from brain of a fatal case of Malignant Tertian Malaria

in which case, under favourable conditions, it may attain the intestine of a suitable host and give rise by segmentation to sporoblasts and finally sporozoits. The latter then behave exactly like the merozoits and soon make their way into epithelial cells, where they become schizonts. Should the sporont be left free, it gives rise, after varying periods of incubation, to sporoblasts, which are originally without any protecting membrane; this they soon secrete and become protected until they can attain some suitable host. The actions of the intestinal juices cause them to open and permit the sporozoits to escape and infect epithelial cells from which the cycle begins afresh.

Plasmodium malariæ.—Of the genus plasmodium, belonging to the hæmosporidia, this is the only species which is parasitic to man, and of this three varieties are recognised; these are *P. malariæ* or the parasite of quartan ague, *P. vivax* or the benign tertian parasite, and *P. immaculatum* or the parasite of malignant tertian or tropical malaria. Other species of the genus affect monkeys, birds, bats and even reptiles, so that the malarial parasites are not confined to the warm-blooded animals. The life-cycle of the malarial parasites is of the same type as that of the coccidia, but differing therefrom in that the schizogony and sporogony are in different hosts.

The three human malarial parasites produce fevers which recur at regular intervals, each access of fever coinciding with the endogenous sporulation of the parasite and the liberation of merozoits which attack fresh red blood-corpuscles. Thus, in quartan ague a schizogenous generation takes seventy-two hours; in the benign tertian parasite each generation takes forty-eight hours; while in malignant malaria sporulation is irregular. The quartan parasites cause the corpuscles to lessen in size. Corpuscles attacked by the benign tertian parasite increase in size, but become paler. The effect produced by the malignant tertian parasite is sometimes to enlarge and at others to lessen the corpuscle. This type of malarial fever is distinguishable by the sausage or crescent shape of the gametocytes in the blood-cells.

Primary infection occurs by the introduction of sporozoits into the blood by the proboscis of an infected mosquito belonging to the anophelina. Each sporozoit penetrates into a red blood-cell, grows rapidly within it, and becomes a schizont. In the fully formed schizont, the nucleus divides up into some nine to twelve masses in the quartan parasite, twelve to twenty-four in the tertian, and a variable number in the pernicious parasite. A corresponding number of merozoits are formed, the whole forming the so-called rosette. On completion of sporulation, the merozoits escape into the blood and re-infect fresh corpuscles. In pernicious malaria, sporulation takes place in the internal organs and bone-marrow; while in quartan and tertian fever it occurs in the peripheral blood. This is the so-called endogenous cycle and goes on only in the vertebrate host; as a result of this constant reproduction of merozoits by schizogony a reaction on the part of the host is brought about; this stimulates the parasite to produce sexually differentiated sporonts, destined for exogenous reproduction. These sporonts develop much more slowly than the schizonts, and are characterised by an absence of ring-forms in the blood-cells. The sporonts are of two kinds, namely, the male and female gametocytes. The male sporonts have a clear cytoplasm with a large nucleus; the female have a granular cytoplasm but a small nucleus. In the pernicious malaria parasite, the sporonts are crescentic or sausage-shaped. In the male crescents the pigment granules are evenly scattered, while in the female they are collected round the nucleus. (Plate XI.) The sporonts are less amœboid than the schizonts. If not taken

up by a mosquito, the male sporonts or micro-gametocytes appear to die off, but the female, or macrogametocytes are more resistant and capable of parthogenesis and the production of fresh schizogenous generations, which are the probable cause of relapses so common in malarial fevers.

When taken up by the mosquito, the ripe gametocytes at once undergo changes. In the male ones the nucleus gives off chromidia which travel to the surface, and motile threads, four to six in number, are shot out from the surface. These microgametes lash about until detached from the gametocyte, which perishes. In the female gametocyte, no change occurs except the elimination of a part of the nuclear substance until fertilisation is brought about by the entry into it of a microgamete. The chromatin of this male element fuses with the nucleus of the macrogamete, and forms a fertilisation spindle. This fertilised female element or zygote now elongates and develops into a motile gregarinoid body, termed a vermicule or *ookinete.* By its own activity, the vermicule pushes its way into the wall of the mosquito's stomach and there comes to rest as a sphere with a delicate

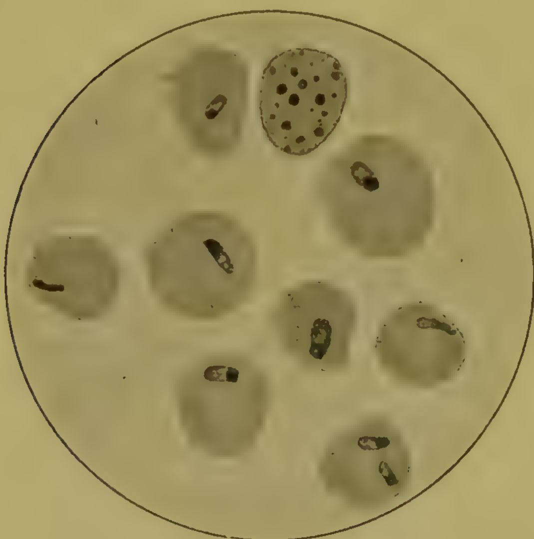

Fig. 99.—Piroplasma bigeminum in Blood of an Ox.

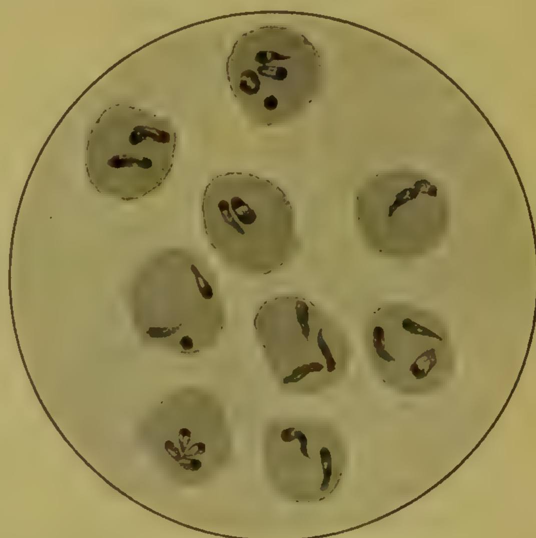

Fig. 100.—Piroplasma parvum in Blood of an Ox.

membranous wall. Within this cyst, sporoblasts form, and by further nuclear changes each sporoblast gives rise to sporozoits, until the cyst may contain ten thousand of them. When ripe, the sporozoits are set free as minute, actively motile, spindle-shaped bodies. These pass to the secreting cells of the salivary glands of the mosquito. When this insect next takes a feed of blood, the sporozoits in the salivary gland pass down the proboscis into the blood of a vertebrate host, in whom they start a fresh cycle of generations. The entire exogenous cycle in the mosquito lasts some ten or twelve days. The human malarial parasites are transmitted by a mosquito of the genus *anopheles ;* those of birds by a gnat of the genus *culex.* The intermediate host for the malarial parasites of monkeys is not known.

Piroplasma.—In this family are included a number of organisms which are parasitic to cattle and dogs, but only one which is apparently parasitic to man. This is the so-called *P. hominis*, the cause of the tick fever of the Rocky Mountains. The diseases produced by these parasites in their respective hosts are generally of a similar type, and in their acute form the chief symptom is hæmoglobinuria following a rapid destruction of

red blood-cells. The invertebrate host has been found in all cases to be some species of tick.

The best-known forms of infection by the piroplasmata are :—Texas fever in cattle due to *P. bigeminum* (Fig. 99); a similar disease among European cattle caused by *P. bovis*; and red-water fever of cattle in Rhodesia and the East Coast of Africa due to *P. parvum* (Fig. 100). Other known species are :—*P. ovis* in the sheep; *P. equi* in horses; *P. canis* in wolves and dogs; and *P. muris* in rats. The parasites are pear-shaped forms varying from 1 to 3 or even 4 μ in size occurring singly or in greater numbers inside blood-corpuscles. A common arrangement is in pairs, especially so in Texas cattle fever. Spherical or ring forms are occasionally seen, and also a so-called bacillary form, in which the body is rod-shaped with the chromatin mass at one extremity. This type is characteristic of *P. parvum*. As stated above, the intermediary host in all cases appears to be a tick, and a given species of piroplasma may be transmitted by more than one species

FIG. 101.—SARCOCYSTIS MIESCHERIANA IN THE MUSCLE OF A PIG (AFTER KÜHN). × 30.

FIG. 102.—SARCOCYSTIS TENELLA IN THE MUSCLE OF A SHEEP (AFTER KÜHN). × 50.

of tick. Very little is known as yet regarding the life-cycle of any of these parasites.

Sarcosporidia.—The parasites of this order are found in the striated muscles of mammals and birds; they are also said to occur in reptiles. They are best known in the pig under the name of "Miescher's tubes" or **Sarcocystis miescheriana** (Fig. 101) and in man as "psorosperms." It is probable that the human parasite is identical with **S. tenella** or that known to occur in the sheep. (Fig. 102.) In the muscles of an infected animal white streaks are visible to the naked eye, as fine white lines between the muscle fibres. Examination with a low power shows them to be composed of tubular granular masses, several millimetres long and about twice as thick as the muscle fibres. They all taper towards the extremities. Under a higher power, a capsule can be made out, while the contents are pale, crescentic, reniform corpuscles, rounded and slightly attenuated at the ends, and often containing a vacuole. In the larger capsules, there are formed tubes of the second and third degree, or spherical masses, each surrounded by a thin capsule, one within the other. On teasing out a part of the fresh muscular tissue, many of the tubes become broken, and innumerable isolated crescentic spores are obtained. No movement is possessed by the tubes or

individual spores. From the crescent-shaped bodies, which are considered as the typical contents of the tubes, there proceed nucleated forms resembling gregarines, which on the addition of an acid emit two filaments from one end. The transfer of these structures to other warm-blooded animals by inoculation, or in food, has hitherto failed. The prevalent belief is that they enter the animals by an intermediate stage of development, probably passed in a snail.

Infusoria observed as parasites in man belong to the order *heterotricha*, having the whole body covered with fine cilia, but stouter cilia about the peristome. Two genera include species parasitic to man, namely *Balantidium* and *Nyctotherus*.

Balantidium coli has an oval body 0·1 mm. long and rather less in breadth. Its ecto- and endo-sacs are separate, the latter containing starch, mucus, fat, and other granules. There are usually two contractile vacuoles. The macro-nucleus is kidney-shaped, and the micro-nucleus globular. The peristome is at the anterior end, and passes back on the side of the body to

FIG. 103.—BALANTIDIUM COLI (AFTER LEUCKART).

FIG. 104.—NYCTOTHERUS FABA (AFTER SCHAUDINN).

the posterior pole, where it ends in an anus. This parasite infests the large intestine of man and the rectum of pigs. It propagates by transverse fission, but conjugation and encystment are known to occur. Transmission to other hosts is effected during the encysted stage. (Fig. 103.)

Nyctotherus faba has been found in the colon of man. It is bean-shaped, with the peristome on the concave side. The macro-nucleus is oval and compact, with a single micro-nucleus, situated close to it. There is a single contractile vacuole at the hinder end of the body, close to an anal tube opening at the posterior pole. Allied species are common in frogs and cockroaches. (Fig 104.)

Before closing this review of the protozoal parasites, a brief reference must be made to certain intermediate forms, for the most part insufficiently understood, which may or may not belong to the protozoa. A few genera only are known, but the following are the more important as human parasites :—

Cytoryctes.—The structures referred to under this name are the alleged intra-cellular parasites of small-pox and vaccinia, named *C. variolæ* and *C. vaccinicæ* respectively. These bodies are essentially intra-cellular parasites of stratified epithelium and occur in two forms, a young cytoplasmic and a later intra-nuclear form ; there is probably an earlier phase,

covering the period from the primary infection to the appearance of the parasites in the stratified epithelium, but this is, as yet, unrecognised. In the earlier known phase, the organisms appear in the cells of the specific lesions as minute amœboid bodies, which reproduce by multiple fission; this process may go on for several generations, and in the case of vaccinia ends here, but in variola passes on to the third stage, characterised by an invasion of the nucleus by the young forms resulting from the fission of the parent cytoplasmic amœba. In the nucleus, sexual gametocytes are said to form, resulting in the development of a zygote from which originate sporoblasts and finally spores. Much of our knowledge regarding these changes and the life-history of cytoryctes is derived from the investigations of Calkins,* Councilman, Magrath, and Brinckerhoff,† whose papers should be consulted in the originals for more precise details. According to Calkins, the cytoryctes should be classed with the Microsporidia.

The foregoing views and accounts of the life-history of cytoryctes have been much criticised, and more especially challenged by Siegel,‡ who places cytoryctes as a genus intermediate between the Sporozoa and the Flagellata. He regards several species of this organism to be the parasitic causes of small-pox, foot-and-mouth disease, scarlet fever and syphilis respectively. He describes these parasites as existing under two forms. The first is mobile and represented by a pear-shaped body, with one end running out into a delicate refringent flagellum. These mobile forms may multiply by binary fission, or by sporulation, following multiple division of the nucleus. As a result of this latter process, the second or non-mobile forms arise; these are of the nature of cytospores and probably represent the resistant and infective phase. The cytospores are able to pass through the finest porcelain filter, and those of different species may show "characteristic differences of parasitic habitat."

It is difficult to reconcile the divergences between these two sets of observations, but it may be that, as a better technique is evolved, many points of apparent difference as to facts will be found to harmonise. Siegel's claim that *Cytoryctes luis* is the cause of syphilis is in conflict with the view that *Treponema pallidum* is the infecting agent in that disease; but it is not beyond the bounds of possibility that the former represents one stage, and the latter another, of the life-cycle of the same organism. For the present, in view of these conflicting statements, it will be wiser to suspend judgment as to the precise nature of any of these apparently parasitic forms, and merely call attention to the wide field of parasitology which yet remains to be explored.

PLATYHELMINTHES.

These are symmetrical worms having a flat or tape-like body. The mouth is either at the fore-end of the body or shifted more or less backward on to the flat abdominal surface. In the majority of these worms the alimentary canal is simple; in one group, the cestodes, the alimentary canal has disappeared entirely. Nearly all the platyhelminthes are hermaphrodite. Reproduction is usually sexual, often combined, however, with

* Calkins: "The Life-history of Cytoryctes variolæ," *Journ. Med. Research*, 1904, xi. pp. 136–172.

† Councilman, Magrath, and Brinckerhoff: "The Pathological Anatomy and Histology of Variola," *Jour. Med. Research*, 1904, xi. pp. 12–135; *ibid.* pp. 173–179.

‡ Siegel: "Untersuch. u. die Aetiologie der Pocken u. der Maul-und Klauenseuche"; *also* "Untersuch. u. die Aetiologie des Scharlachs"; *also* "Untersuch. u. die Aetiologie der Syphilis"; *Anh. Abhandl. Akadem. Wiss. Berlin*, 1905.

asexual methods such as budding or segmenting. The greater number of these worms live as parasites on or in animals; a few live partly free in water, and in a few rare cases also on land. The platyhelminthes are divided into three classes:—(1) The *turbellaria* or eddy-worms; these live in water or on land; they furnish no known parasites to man. (2) The *trematodes* or sucking worms, commonly known as flukes. (3) The *cestodes* or tape-worms.

FIG. 105.—FASCIOLA HEPATICA (AFTER LEUCKART).

Fasciola hepatica.—This is the common fluke, and measures from half to three-quarters of an inch in length. Its habitat is in the gall-ducts and gall-bladder of man, of sheep and other ruminants. The number of cases of human infection by this parasite are not large, but they are sufficiently numerous to indicate that it may be the cause of severe disorders, though not always fatal. The free life of the embryos is generally short, and in place of making their way into some intermediate host, such as one or more species of fresh-water snails, as do some allied forms, the embryos become encysted upon water plants and other objects, attached to which they are transferred to their final host, in whose body they attain maturity.* The eggs of *F. hepatica* (Fig. 10, Plate XII.) possess a thin brownish shell; they are operculated, and measure 140 μ by 90 μ.

Distomum lanceolatum.—This is the smallest common European fluke, being about one-third of an inch long, and in the few cases in which it has been found in man has been once associated with the last species. Its life-history is not accurately known, but is similar to that of *F. hepatica*. The eggs of this parasite measure from 40 μ to 45 μ in length by about 20 μ in breadth; they have a thin brown operculated shell, and generally contain an already formed, partially ciliated embryo (Fig. 11, Plate XII.).

FIG. 106.—DISTOMUM SINENSE. × 6. (AFTER KATSURADA.)

Distomum sinense and **D. conjunctum.**—The first of these is a small fluke, measuring seven-tenths of an inch in length, and found infesting the livers of Chinese and Japanese, in whom it often causes a severe hepatitis (Fig. 106). Its cercaria, or larval stage, is not known, but probably infests a fresh-water mollusc. The eggs of the entozoon are oval, with a double contour and an operculum. Their average size is about 30 μ, or say $\frac{1}{800}$th of an inch. *D. conjunctum* is only three-eighths of an inch in length, and has been found in the livers of both dogs and man. No more is known of its life-history than of *D. sinense*. Its eggs are similar in shape and appearance to those of the latter, the only distinction between them being that the eggs of *D. conjunctum* are slightly the larger of the two.

Distomum crassum, sometimes called *D. Buskii* from the name of its first discoverer, is the largest fluke found in man, measuring from 1 to 3 inches in length. Its favourite habitat is the duodenum. Neither its larval state nor intermediate host are known, though this latter is thought to be a species of Chinese oyster. The eggs of this fluke are large,

* Thomas: "The Life-history of the Liver Fluke," *Quart. Journ. Microsc. Sci.*, 1883, xxiii. p. 99.

125 μ by 75 μ, thin-walled, oval, and filled with granular and somewhat highly refracting matter.

Distomum heterophyes is a very minute fluke, measuring no more than from 1 to 1·5 mm. It has only been twice found in man; on both occasions in Egypt. Its eggs are minute, oval, reddish brown and with a thick shell. Size, about 25 μ by 15 μ.*

Amphistomum hominis.—Very little is known of this parasite, which, until now, has only been found in India. The eggs possess a shell with an operculum, are oval-shaped, and measure 150 μ long by 72 μ broad. Its habitat is the intestine, but nothing is known of either its larval stage or life-history.

Distomum Ringeri.—Discovered first by Ringer in North Formosa, it has since been found also in Japan and Corea, usually inhabiting the lungs, but also the brain and sub-peritoneal tissues. It is a small, oval, thick, reddish brown fluke, measuring about one-third of an inch in length by one-fourth of an inch in breadth. It has two suckers, the oral, which is terminal, being slightly the larger; the ventral sucker is placed about one-third of the animal's length posterior to the oral one. This parasite gives rise, when situated in the lungs, to severe hæmoptysis, and the diagnosis of this pulmonary helminthiasis depends mainly upon the recognition of the ova of this fluke in the sputum. These ova are dark brown bodies, measuring about $\frac{1}{300}$th of an inch by $\frac{1}{500}$th of an inch. They have a plain thick shell, the broader end being closed by a lid. Under a suitable condition of moisture, a ciliated embryo develops within each egg. Manson, who has closely studied the eggs of this fluke, considers that, in water, the embryo distome seeks out an intermediary host in the shape of some mollusc or other fresh-water animal, and " that, after entering this, either by being swallowed or by penetrating its integument, it undergoes the complex metamorphosis peculiar to the distomes. When this is completed it is either swallowed by man, while still in its intermediary host; or, escaping from this, it attaches and encysts itself on some vegetable or other animal, and there awaits the chance of being transferred to a human stomach, from whence it afterwards works its way to the lungs of its definitive host."

Bilharzia hæmatobia.—This is a trematode worm, which differs from those previously described by having the male and female reproductive organs in separate individuals. The male is opal-white, and measures about $\frac{5}{16}$ths of an inch in length, by $\frac{1}{25}$th of an inch or more in breadth. The female is grey or brownish in colour, and both longer and thinner than the male worm. Both male and female possess two suckers; the body of the male assumes a cylindrical shape, due to the lateral borders being bent inwards, constituting in this manner a sort of gynæcophoric canal for the female. The adult worms are generally found in the portal vein and its branches and tributaries; also in the small veins of the bladder, ureters, and inferior cava. They are frequent in Africa, especially Egypt, The Cape, and Natal; also on the coast of Arabia. There is likewise evidence to show that they occur in the Ile de Bourbon, Mauritius, and Brazil.

Located within the visceral veins, the adult parasites, if present in any large numbers, will soon make their presence felt. If many worms exist, a violent hæmaturia may occur, without any warning. Experience has shown that, although hæmaturia invariably accompanies the disorder, the bleeding – in cases where but few worms exist – may be so slight as to escape not only the eye of the victim, but even also that of the medical attendant.

* Looss: " Weitere Beitrage z. Kentniss d. Trem-Fua. Egypt," *Zool. Jahrb. System*, 1899, xii. p. 699; *see also* Sandwith, in the *Lancet*, 1899, ii. p. 888.

From this it follows that the presence of the disease can only be certainly diagnosed by microscopic examinations of the urine and fæces to detect the eggs. These eggs (Fig. 12, Plate XII.) are bright and translucent oval bodies, with a smooth surface and thin non-operculated shell, possessing a spine situated ordinarily at one end, but sometimes laterally. They have a length of 0·16 mm., and a breadth of 0·06 mm. The embryo is ciliated, and if left in urine soon dies; in water, however, its vitality is both marked and sustained. According to Sonsino, the intermediate host of *Bilharzia* is a small fresh-water crustacean (amphypoda), on encountering which, in water, the free embryo attacks at a vulnerable point, and, by means of the

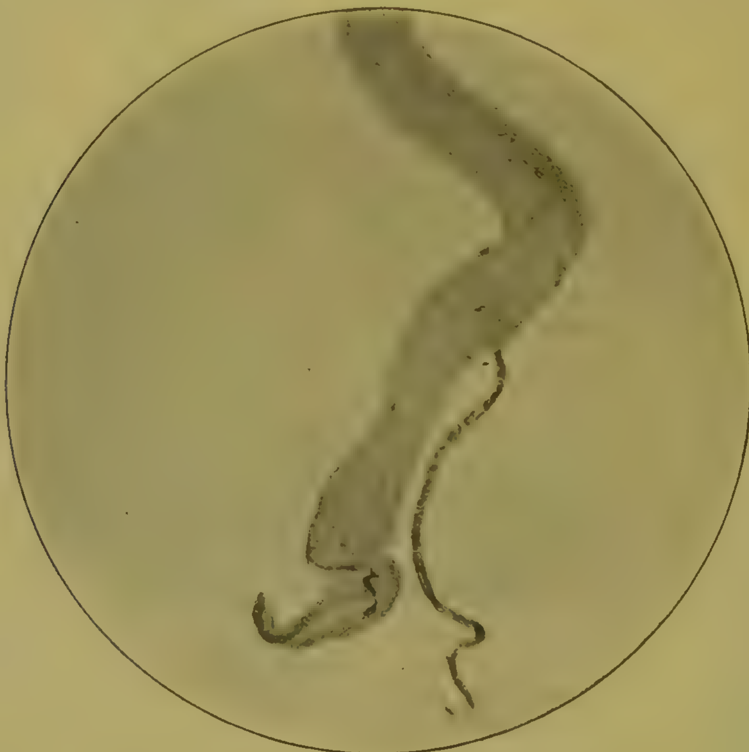

Fig. 107.—Male and Female Bilharzia.
The Whipcord-like Female is in act of adjustment to the Male Gynæcophoric Canal. (From an actual Micro-Photograph taken by Lieut. Col. C. Birt, R.A.M.C.)

papilla at its head, bores and forces its way into the animal's body after having rid itself of its covering of cilia. Having effected an entrance, it proceeds to encyst itself. The encysted larva, being transferred with the crustacean in drinking water to the human stomach, is then set at liberty; afterwards, penetrating the intestinal walls, it arrives in the portal vein, where, presumably, it completes its development.

At one time it was suggested that the re-introduction of this parasite to man might be made through the skin, urethra, or anus whilst bathing, instead of by the digestive tract, but in the face of the precise observations of Sonsino, this hypothesis is as untenable as it is unnecessary.*

Schistosomum japonicum.—This fluke was first noted by Katsurada in Japan in some human cases. He further found the same parasite in dogs and cats. A few months later a similar parasite was found by

* Sonsino: "Ric. s. syilluppo d. Bilharzia," *Giornale R. Acc. Med. Torino*, 1889, xxxii. p. 380; see also *Lancet*, September 9, 1893.

Catto * in sections from mesocolon of a Chinaman at Singapore. Morphologically the S. japonicum is not unlike the Bilharzia hæmatobia. It is, however, smaller and has a smooth non-tuberculated integument; the posterior sucker is also rather large. The ova are without spines. Nothing is known of the life-history of this schistosomum. The ova contain a ciliated embryo, which may develop in the fæces before they are evacuated. It is probable that this parasite is widely spread throughout China, Japan and Formosa. Catto suggests that it has been often found. but its ova in the dejecta mistaken for those of Uncinaria duodenale, to which they bear a close resemblance.

The Cestodes include the great group of tape-worms, which in reality are a multitude of organisms or zooids, arranged in single file. The head itself is merely the topmost zooid, modified in shape, and armed with sucking discs, so as to form a means of anchorage for the whole colony. An ordinary human tape-worm consists of about a thousand zooids or proglottides, each of which is sexually complete, and, when mature, capable of generating about 30,000 eggs. Assuming that the entire colony of a thousand zooids is renewed every three months, it follows that a single tape-worm annually disperses about 120,000,000 eggs. Fortunately, compared with the quantity distributed, the number of eggs that survive and come to perfection as tape-worms is infinitesimally small. The chief cestodes, parasitic to man, are the following:—

Fig. 108.—Head of T. saginata.

Tænia saginata, sometimes called *T. mediocanellata*, is the only cystic tape-worm with an unarmed head which occurs in man. It is, at the same time, the largest of the human tæniæ, being about 8 metres long when extended, and composed of from 1000 to 1300 segments. These segments are remarkable for their size, length, and firm appearance. The largest measure 20 mm. in length, and from 5 to 7 mm. in breadth. The head of this parasite is hookless, has a flattened crown, with a pit-like hollow in the middle, and has four large and very powerful suckers, which, however, usually project only slightly, and are frequently surrounded by a black, broad, pigmented border (Fig. 108).

The complete development of the germ-producing organs takes place at about the 600th segment, while the embryos only attain maturity at about the 1000th segment. Each segment contains male and female organs, while the number of so-called "ripe" segments, present at any one time, averages about 200. The new formation or growth of the segments is so rapid that some ten proglottides are separated daily, even when, as is the rule, only a single worm is present. The eggs of this worm (Fig. 5, Plate XII.) have a thick shell, with a border of little rods. They are generally oval, and provided with the primordial yolk-skin; their average size is 0·03 mm. The normal abode of this parasite is the small intestine, to the walls of which it is fixed. usually towards the upper end. The precise duration of its life is undetermined, but seems to be very long. The eggs are commonly expelled with the dejecta of the host, and the contained embryo does not undergo further development, unless it obtain access to the alimentary canal of the ox. From here the embryo passes into the voluntary muscles

* Catto: "Schistosoma Cattoi," *Brit. Med. Journal*, 1905, i. p. 11; also *Journ. Trop. Med.*, 1905, vii. p. 70.

of the animal, where it remains as a bladder-worm, a simple scolex, known as the beef-measle or *Cysticercus bovis*. An ox, affected with this parasite, that is, acting as the intermediate host for the *T. saginata*, may contain many hundreds of the cysticerci, or bladder-worms, within its muscles. On the flesh of the animal (either raw or imperfectly cooked) so affected passing into the alimentary canal of man, the bladder-worms develop into the sexually complete adult form known as the *T. saginata*.

The cattle in Abyssinia and the Punjab appear to be specially infected with the cysticerci of the *T. saginata*, this parasite being by far the most common of the tape-worms found in man in those countries. The only animal, besides the ox and goat, which has hitherto exhibited the bladder-worm of *T. saginata*, is the giraffe.

How long the bladder-worm of *T. saginata* remains living in its host cannot at present be decided, but we may reckon the length of its stay

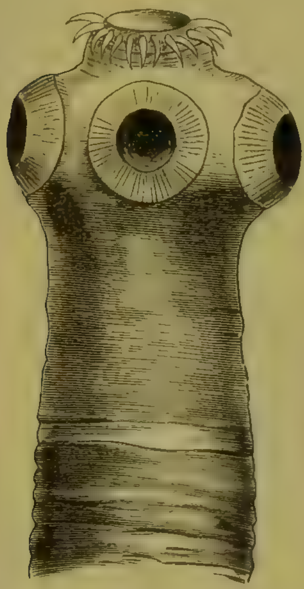

Fig. 109.—Head of T. solium (after Leuckart).

Fig. 110.—Muscle containing Cysticerci cellulosæ (after Leuckart).

there at several years. It, however, survives only some fourteen days after the death of its host, and if the parts putrefy, will only survive a still shorter time. As regards the term of infection in man, usually some nine to twelve weeks must elapse after the ingestion of the *cysticercus* before the *T. saginata* gives off the first proglottis.

Tænia solium.—This cestode, though usually regarded as the common tape-worm, is comparatively rare. It is chiefly found amongst the poor, who are large consumers of pork, which is often imperfectly cooked. In Iceland and Germany the pork tape-worm is rather more common than the beef tape-worm.

In size, thickness, and number of segments, this species is considerably less than the last. Extended, it rarely exceeds 3·5 metres in length, while its segments average 850, and of these not more than 100 are ripe proglottides. The size of the greatest of these segments is about 12 mm. by 5 mm. The head (Fig. 109) is about the size of that of a pin, has a spherical shape with prominent suckers. The apex is often coloured black, and bears a medium-sized rostellum, with generally twenty-eight hooks. The sexual organs are usually fully developed at about the 400th segment. The eggs (Fig. 6,

Plate XII.) are almost round, being enclosed in a firm shell, whose outside is covered thickly with little rods. Sometimes the original clear egg-membrane persists within the shell. The course of development and life-history of this parasite is analogous to that of *T. saginata*, with the exception that the corresponding bladder-worm (*Cysticercus cellulosæ*) has a special preference for the muscles of the pig, but, according to Leuckart, is occasionally found in other animals. Its occurrence in the pig is usually very abundant, where it constitutes measly pork (Fig. 110). The great majority of the cysticerci average between 3 and 4 mm. in size, but some are larger, others again are smaller. They are killed by exposure to a temperature of 50° C.

It must not be overlooked that, although the pig is the most frequent intermediate host for this bladder-worm, man himself may become the intermediate bearer, as this cysticercus develops also within the human body. The above fact leads us to the question, By what way does man become infected by these embryos? An infection by some means must precede the appearance of cysticerci, and its channel can only be by the alimentary canal. The most direct and frequent source of infection is in the eggs, which are dispersed about the abode of the tape-worm, and also widely distributed in the open air with the excrement. These may reach man's digestive tract either by water, food, or by the hand. This latter vehicle of infection is by no means unknown in the case of children and the insane, while the normal adult tape-worm patient may readily infect himself with the proglottides of *T. solium* during sleep, by lifting the hand to the mouth.

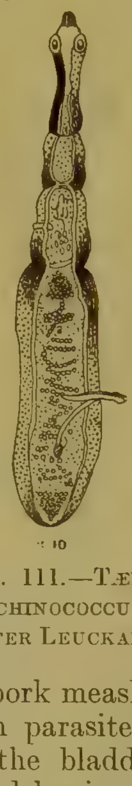

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FIG. 111.—TÆNIA ECHINOCOCCUS (AFTER LEUCKART).

These considerations suggest the special need of cleanliness when an inmate of the house suffers from this parasite. The linen of the patient should be frequently changed, the buttocks, perineum, and hands frequently washed, the excreta carefully removed, and all voided proglottides burnt without touching the hands. Of all persons, the patient is himself in greatest danger of infection. The experimental evidence of this danger of self-infection has been supplied by Küchenmeister, who reared both mature and immature tænia of this species in condemned criminals; while, under Leuckart's auspices, several persons voluntarily allowed themselves to become infected by swallowing fresh and living pork measles.

Tænia acanthotrias.—This is a somewhat uncommon parasite of man, and has hitherto only been observed in America. Only the bladder-worm is as yet known, being very like *Cysticercus cellulosæ*, and having its habitat in the muscles and brain of man. "It is distinguished by the arrangement and structure of the hook apparatus, which is composed of a triple circle of from fourteen to twenty-six slender hooks." Leuckart and Weinland both maintain that this *Cysticercus acanthotrias* represents an independent species. The related Tænia is unknown, but it probably lives in the human intestine like *T. solium*; if so, the bladder-worm may possibly be found in some animal, such as the ox.

Echinococcus hominis.—Man is occasionally affected with a dangerous parasite under the name of hydatid disease, which commonly affects the liver, but may occur elsewhere. It is really the cysticercus stage of a tape-worm, which lives in the intestines of the dog, jackal, and wolf, and called the *Tænia echinococcus*. The adult tape-worm (Fig. 111) is of comparatively small size, its total length being only some 5 millimetres;

it has only three or four segments, of which the last, when mature, exceeds all the rest of the body in size. Its head is characterised not merely by its small size, but also by the possession of a prominent crown which surrounds the bulging rostellum, on which are from twenty-eight to fifty thick solid hooks, arranged in two series.

Behind the four suckers the head narrows to a neck, which then passes into the unsegmented anterior part of the body. The first segment is but faintly differentiated; the second is defined and contains elementary sexual organs. The third and last segment exhibits all the characters of sexual maturity, and contains some 500 spherical hard-shelled eggs, in which are the familiar six-hooked embryos. Before the last or ripe segment is liberated, a new joint appears; so that, for awhile, four proglottides are distinguishable instead of three.

On the escape of the eggs, the contained embryo does not undergo further development unless received into the body of the pig, ox, or possibly some other animals, and man, in whom, after burrowing to various parts of the body, more particularly the liver, it assumes the larval stage of a *cysticercus* or hydatid cyst. Unlike other cysticerci, this bladder-worm increases indefinitely in size, and also forms within itself secondary cysts, some of which, the so-called brood-capsules, contain one or more echinococci (scolices) and remain minute, while others, containing no scolex, enlarge and form other or daughter cysts, which again may produce new cysts by a process of budding. Separately, these scolices, formed within the parent cysticercus, represent as many tape-worms, and collectively they amount to many thousands. Thus, when a dog or a wolf swallows one of these hydatid cysts and its contained offspring, all the heads of the colony become converted into sexually mature *T. echinococci* in the intestine of the new host. This metamorphosis of the echinococcus heads into tape-worms takes place with great rapidity. Leuckart's feeding experiments resulted in mature worms being found in the seventh week. How long the adult worm lives is not known, but analogy suggests that its period of existence within the intestine of the dog is not very short. Since the *T. echinococcus* especially inhabits the intestine of the dog, and the dog is one of the few animals in closest association with man, we are justified in regarding this animal as the only source of the human echinococcus disease. It is not difficult to understand how cattle become infected; for the proglottides and eggs of the echinococcus tape-worm, voided so constantly, and in such large numbers, by the dog, readily find access to straw, grass, or even water, and with those articles of food and drink are consumed by the oxen. In the case of man, possibly the sequence of events is not much different. As with cattle, both proglottides and eggs of the tape-worm from the dog may in many ways be carried in food, especially uncooked vegetables, such as lettuces, or on the hands to the mouth, and thus reach the intestine. Probably a greater risk of infection lies in the habit which dogs have of licking the hands and faces of their masters, and that often after they have been smelling and snuffing about other dogs. These are considerations which should prevent our too familiar association with dogs, more particularly to avoid their licking us, and frequenting dwelling-rooms or kitchens. Moreover, full precautions should be taken to prevent infection of dogs by embryos of echinococcus, as may occur in slaughter-houses, where the so-called bladder-worms, or echinococcus cysts, from slaughtered and infected animals are often carelessly thrown down. It is needless to say that dogs eating such echinococcus bladders would soon develop them into sexually mature echinococcus tape-worms.

Tænia nana.—Judging by the few cases which have been observed this is an uncommon parasite of man. It was originally discovered by Bilharz in Egypt, who describes it as being a small tape-worm, from 12 to 20 mm. long, and with a maximum breadth of half a millimetre. The front half of the body is thread-like, but posteriorly it enlarges somewhat quickly. The head is spherical and bears four suckers and a central rostellum provided with a single circle of from twenty-two to twenty-eight extremely small hooks. The number of segments is not more than 170, of which the last contain thirty or more ripe eggs. Each segment is very short, being about four times as broad as long. The eggs (Fig. 7, Plate XII.) are oval, with a thick but not radially striated shell. They measure from 30 μ to 150 μ in length, and 40 μ in breadth.

Very little is known of the life-history and origin of this worm, but, arguing from what is known of some allied species, it is supposed that the larval stage is passed in some insect or snail.

Fig. 112.—Tænia nana (after Leuckart).

Tænia flavo-punctata.—This is another very uncommon human parasite. Its length is about 1 foot. The front half of the animal consists of unripe segments, each of which exhibits posteriorly a central yellow spot; this is the distended *receptaculum seminis*. In the posterior half of the body the segments are longer and broader, and without the yellow spot. In this situation the segments are of a brownish grey colour, owing to the abundant development of eggs. The eggs are very large (Fig. 8, Plate XII.), having a diameter of some 70 millimetres. They have a smooth double envelope, which under high power can be seen to be radially striated. Nothing is known of the life-history of this worm; nor has its head been satisfactorily examined.

Tænia Madagascariensis.—This intestinal cestode has only been met with in warm climates. It reaches a length of about 20 cm., with a breadth of 2·5 mm. It has usually 100 segments, in the interior of which are a number of small oval bodies, arranged in transverse rows, alternating with each other, but without touching at any point. These are balls of eggs, and amount in each proglottis to quite 150; the number of eggs in each ball being about 400. The head of this worm has a rostellum with about ninety hooks. The worm itself has only been met with in children, and its life-history is unknown.

Tænia cucumerina.—This species of tape-worm is most frequent in cats and dogs; it has also been found in young children. Fig. 113 shows this worm in its natural size. The head is club-shaped, with a rostellum surrounded with four rows of hooks. While the first forty segments are insignificant in size, the remainder lengthen so much that they ultimately become four times as long as they are broad; the corners of these proglottides are rounded. The ripe segments are of a red colour, from the masses of brownish eggs shining through.

The intermediate host of *T. cucumerina* is the dog and cat louse, in which it passes its larval condition as a cysticercoid. The probable life-history is somewhat as follows. The eggs of the adult tape-worm make their way sooner or later from the excreta to the hairy skin of the cat or dog, and

thence to *Trichodectes* or lice living upon it, in the interior of which insects the eggs change into cysticercoids. Cats and dogs are constantly licking themselves and devouring the hosts of these bladder-worms; from them the infection of man takes place, either from the tongue of the dog, which returns caresses by licking, or through the hands which stroke these animals. In children, who treat both cats and dogs with familiarity, the facilities for infection are even greater than in adults.

FIG. 113.—TÆNIA CUCUMERINA (AFTER LEUCKART).

Bothriocephalus latus.—This is a short-jointed, broad and flat tænia of very considerable length, attaining usually some 27 feet. The number of segments may amount to as many as 3500. The body is thin and flat like a ribbon, especially towards the sides, while the median portion projects as a sort of pad or ridge. In the ripe proglottides, the uterus constitutes a characteristic feature of this tape-worm, being peculiarly stellate or rosette-shaped. The head is ovoid, $\frac{1}{10}$th of an inch long, and has two longitudinal grooves or suckers, but no hooklets. The eggs (Fig. 9, Plate XII.) are oval, about $\frac{1}{400}$th of an inch in their shorter diameter, and provided with an operculum or lid at one end; the shell is brown in colour. The embryo is a ciliated organism with six hooks, and, in the free state, can live and swim about in water for more than a week. Subsequently the ciliated mantle is discarded. The intermediate host of this worm is believed to be certain kinds of fresh-water fish, particularly the pike, into which the embryos enter directly from without by boring. Although all attempts to bring about an immigration of these embryos of *bothriocephalus* into fish have failed, the observation of larval forms of this tape-worm in the pike and turbot are sufficiently definite to warrant the belief that the intermediate host is one of these fishes. Possibly there may be two intermediate hosts, the first being an aquatic invertebrate.

FIG. 114.—HEAD OF BOTHRIOCEPHALUS LATUS.

As found in the pike, the larval worm of *Bothriocephalus latus* is not cystic, but round, long, narrow and distended. Its length varies in this stage from 1 to 2·5 mm. Not only in man, but in cats and dogs, feeding experiments have given positive results.

NEMATODES.

The thread-worms, as a rule, are elongated round worms having a length from about 1 mm. to 70 cm., according to the species. The outer surface of the body is smooth or annulated and provided at certain points with papillæ or bristles. The anterior end, carrying the oral aperture, is slender, while the posterior is rounded or pointed. The sexes are nearly always separate, the male being smaller than the female; the posterior end of the male is often spiral, while that of the female is straight. Some nematodes live free in fresh or salt water, in soil, mud or decaying vegetable material; others live as parasites in the various organs of animals.

Only a few species are viviparous. The usual sequence of events is fertilisation within the uterus, then extrusion of eggs; the shape of the eggs is to a large extent characteristic of the different species (Plate XII.). The eggs

may be deposited either before or during segmentation or with the embryo perfectly developed. The development of the extruded eggs takes place after varying lengths of time in water, in moist earth, or in the open. Many of these eggs can retain vitality even after prolonged desiccation. In the free living nematodes, the embryos, apart from their size, resemble their parents and are fully developed on leaving the egg. In some parasitical species, the young are larvæ, as they present characters which are lost afterwards. The manner of conveyance of these larval forms to the host varies; in some cases the conveyance into the definitive host is direct after development within the eggs, which are eaten by the host; in other cases, the larvæ hatch in the open, live free in another form, grow and finally gain the intestine of the host by means of water or other vehicle, when they lose their larval characters and assume the parental form. Frequently the larvæ may make use of one or even two intermediary hosts. In a certain number of nematodes, heterogeny occurs, or alternations of sexual generations with each other within the same species, as, for instance, in rhabdonema.

The following are the chief nematodes observed in man:—

Rhabdonema intestinale.—This nematode was discovered by Normand in excrements passed by French soldiers suffering from the so-called Cochin China diarrhœa. It has since been found in the West Indies, Brazil, Egypt, Ceylon, Italy, and Germany, and commonly associated with anchylostoma.

FIG. 115.—RHABDONEMA INTESTINALE (AFTER SONSINO). *a*, Adult female parasitic form; *b*, Embryonic form; *c*, Male adult free form; *d*, Female adult free form; *e*, Larval form.

Of the adult parasitic form, only the female is known. She is a thin slender worm about 2 mm. long, the breadth being about $\frac{1}{50}$th of the length (Fig. 115). In the intestine the embryos are quickly hatched from eggs expelled by the worm, thus differing markedly from *anchylostoma*, whose embryos are only hatched after the eggs are voided from the human intestine. The embryos, which are to be found in large numbers in the dejecta of affected persons, are about 0·3 mm. long, and 15 μ thick. They possess a sharp-pointed tail, and being rhabditiform, have a short œsophagus with

two dilatations, resembling somewhat the embros of *anchylostoma.* When discharged with the fæces, on these decomposing, the embryos rapidly die. But if they gain access to foul water, the embryos live and assume one of two different forms of development, according to the temperature. Under a low temperature (20° C.) they become filariform larvæ, capable, if directly re-introduced into man, of growing into the adult parasitic form, without alternation into the adult free form. Under a higher temperature (30° C.) the embryo grows into the adult free form. This was formerly called *Anguillula stercoralis*, and consists of males and females. It is shorter and thicker than the parasitic form. From these are bred rhabditiform embryos, like those from the parasitic worm, and these embryos then grow into filariform larvæ, which only need introduction into the human intestine to develop into the adult parasitic form. The source of infection by this parasite is probably the same as in *anchylostoma*, namely, soil or foul water. The *Rhabdonema intestinale* is also capable of penetrating the skin when in the larval stage, producing a pustular eruption and infection.*

Filariæ sanguinis hominis.—There are three definite species of embryo nematodes which have been found in the blood of man, and to which the term *Filaria sanguinis hominis* may be appropriately applied. Adopting the nomenclature suggested by Manson, to whose writings and investigations we are mainly indebted for the following facts, the three species of hæmatozoa are *Filaria nocturna*, *Filaria diurna*, and *Filaria perstans*. These names have been given on the basis of certain individual peculiarities of habit characteristic of each of the three species. Thus, *F. nocturna* is present in the general circulation only during the night, *F. diurna* only so during the day, while *F. perstans* is present both by night and day. It is essential, for a right comprehension of the somewhat complicated subject of blood filariæ, to grasp the fact that all these organisms are only the embryos of certain other and mature parasites, which live and breed in remote parts of the body, and that, though the embryos may swarm within the blood, it is not necessary, in fact is exceptional, for the parent forms to be present in the circulation. Le Dantec † has suggested that we should speak of the adult as the filaria and of the larva as the microfilaria; this is logical, and it seems desirable that where possible this nomenclature be used.

As seen in freshly drawn blood, the *Microfilariæ sanguinis* are transparent and snake-like animals endowed with great activity. In the case of *F. nocturna* and *F. diurna*, this activity is exhibited chiefly as a constant lashing and wriggling without forward movement; whereas, with *F. perstans*, the wriggling is combined with a vermicular movement leading to distinct locomotion. The characteristic features of the three microfilariæ are well described in the table by Manson ‡ on page 595.

All these microfilariæ exhibit a great tenacity for life, and can be seen alive for many days in ordinary slides, provided the blood be kept fluid by oiling the edge of the cover-glass. Mackenzie has shown that the curious phenomenon of filarial periodicity is in some way connected with the quotidian habits of sleeping and waking; and that if this habit of the host be inverted, so is the periodicity of the filarial parasite inverted. The precise cause of this periodicity is not known, but there is reason to think that it is neither due

* Report of Thompson-Yates Laboratory, Liverpool, 1902, p. 471.

† Le Dantec: *Précis de Pathologie exotique*, Paris, 1900, p. 730.

‡ Manson: "The Metamorphosis of Fil. San. Hom. in the Mosquito," *Trans. Linn Soc. Lond.*, 1884, ii. pp. 10 and 367; *also* "The Fil. San. Hom., Major and Minor: Two New Species of Hæmatozoa," *Lancet*, 1891, i. p. 4; *also* "Geograph. Distrib. of Fil. San. Hom.," *Trans. Seventh Int. Congress of Hygiene, London*, 1891, i. p. 79.

to any intermittent parturition on the part of the parent filaria, nor to any deficiency of oxygen in the blood, as has been suggested by Myers, but rather that it is an adaptation to the habits of their intermediate hosts.*

Microfilaria nocturna.	*Microfilaria diurna.*	*Microfilaria perstans.*
Measures $\frac{1}{75}'' \times \frac{1}{3500}''$.	Measures $\frac{1}{75}'' \times \frac{1}{3500}''$ or thereabouts.	Measures about $\frac{1}{125}'' \times \frac{1}{5500}''$.
Is provided with a sheath.	Is provided with a sheath.	Has no sheath.
Caudal end tapers gradually for one-eighth or one-fifth of the length of the animal and ends in a sharp point.	Caudal end tapers gradually for one-eighth or one-fifth of the length of the animal and ends in a sharp point.	Caudal end tapers more gradually for two-thirds of the entire length of the animal, and is abruptly truncated where it becomes reduced to one-third of the diameter of the thickest part of the body.
Cephalic end rounded off, and has obscure pouting movements produced by the movements of a six-lipped prepuce.	Cephalic end rounded off, and has distinct pouting movements. Minute anatomy not known.	Cephalic end is either conical or truncated, passing from one shape to the other by a peculiar jerking, extending and retracting movement.
From time to time a thick tongue-like organ, provided with a delicate retractile spine, is protruded at cephalic end.	Minute anatomy not known.	From time to time a minute tongue-like organ, provided with a retractile spine, is protruded and withdrawn at cephalic end.
Appears in the blood at night, disappearing from it during day.	Appears in the blood during the day, disappearing from it at night.	Present in the blood both by day and by night.
Has a wriggling but no locomotive movement.	Has a wriggling but no locomotive movement.	Has a locomotive as well as a wriggling movement.
Well-marked granular aggregation about the junction of the middle with the posterior third of the body in some specimens.	Slightly marked granular aggregation about the junction of the middle with the posterior third of the body in some specimens.	Body homogeneous throughout, and no such aggregation.
Has a V-shaped organ or luminous point behind the head. Possibly is a rudimentary vagina.	Has a V-shaped organ or luminous point behind the head. Possibly is a rudimentary vagina.	Has no V-shaped organ.

The life-history and parental forms of two of these microfilariæ are now fairly well understood. The adult form of the *Microfilaria nocturna* is a peculiar nematode, usually associated with chyluria and elephantiasis, and known as the *Filaria Bancrofti*. The adult *F. perstans* are found in the connective tissue or deeper fat of the mesentery. The female measures 70 mm. in length and 0·12 in breadth. The male is only 45 mm. in length; the tail is much coiled, with a large spicule, and four pairs of pre-anal and one post-anal pair of papillæ. A distinctive mark is the bifid tail. As regards the mature forms of *F. diurna* practically nothing is known, though Manson

* Manson: "On Filarial Periodicity," *Brit. Med. Journal*, 1899, vol. ii. p. 644.

has suggested that possibly the long but imperfectly known *Filaria loa* may be the parent form of *Microfilaria diurna*; and that certain hominivorous flies with diurnal habits may be its intermediary host. Manson has found a new and smaller variety of *F. sanguinis hominis* in a West Indian patient.

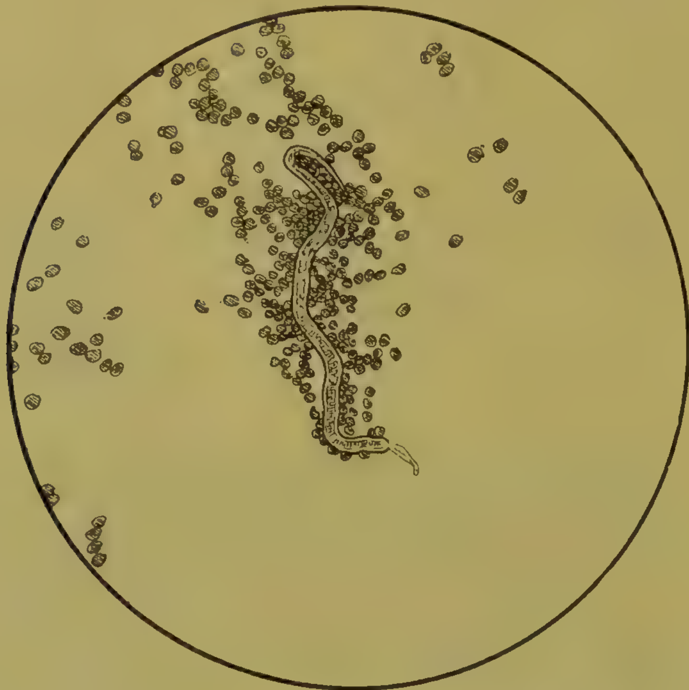


FIG. 116.—MICROFILARIA SANGUINIS HOMINIS DIURNA. × 160.

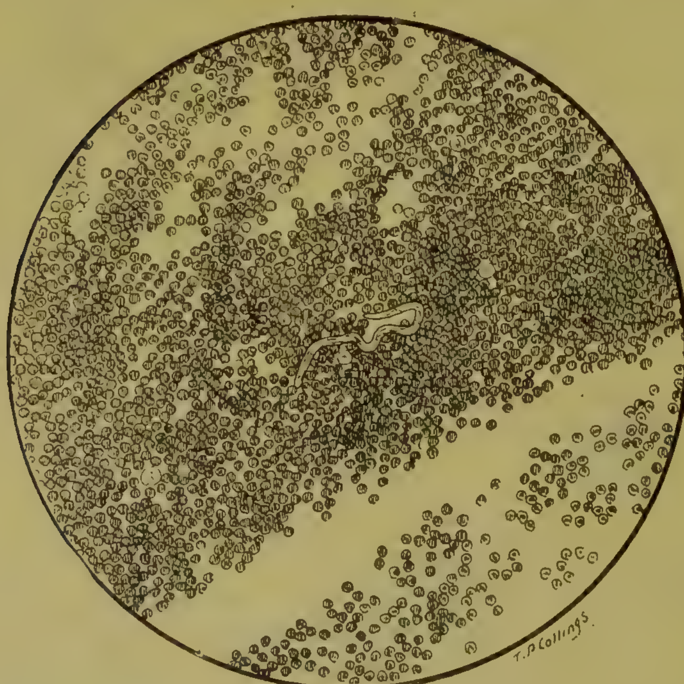


FIG. 117.—MICROFILARIA SANGUINIS HOMINIS PERSTANS. × 160.

Filaria Bancrofti.—This is the mature or parent form of the *Microfilaria nocturna*, having its habitat in the majority of instances, if not in every case, in the lymphatic system. Usually the male and female are found together, but as yet, owing to only imperfect specimens having been examined,

the precise anatomy of the male is not well known. The female is commonly about 3½ inches long and $\frac{1}{100}$th of an inch thick, being smooth and cylindrical. The mouth is simple, circular, and destitute of papillæ; close to and behind the head is the reproductive outlet. The tail is simple, blunt pointed, with anus immediately above the tip. While the alimentary tube is simple, the main part of the animal is occupied by the double uterine or ovarian tubes, usually stuffed with myriads of embryo filariæ at all stages of development.* The embryos on escaping from the parent within the lymphatic system pass periodically into the blood-stream, where they are familiar as the *Mf. sanguinis hominis nocturna.* This periodical migration into the blood is apparently an adaptation to the habits of the mosquito, which is the intermediate host of this parasite. The mosquito, as every one knows, is

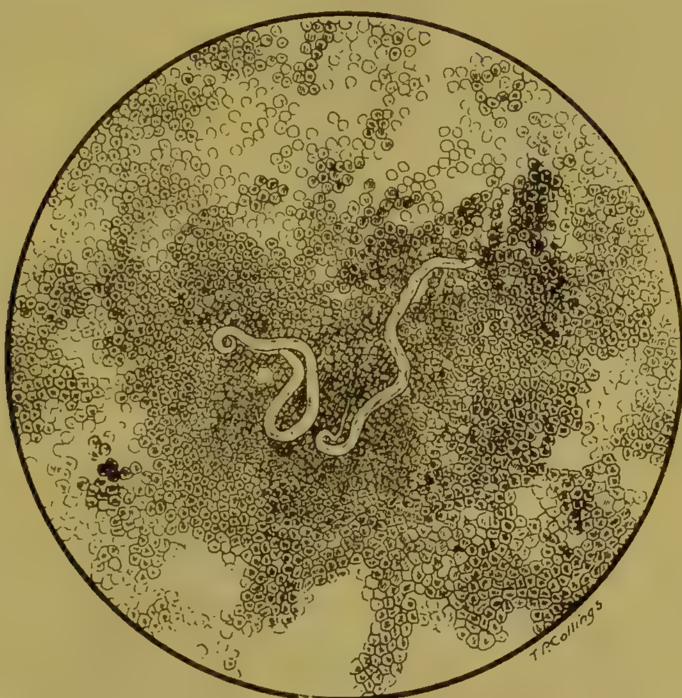


FIG. 118.—MICROFILARIA SANGUINIS HOMINIS NOCTURNA. × 160.

most active at night, and when it bites the human host, these filariæ either curl round or become entangled on its proboscis, and are then quickly transferred to its stomach. The greater number of the filariæ so swallowed by the mosquito are digested or destroyed, but a certain few undergo development inside its body, and when the mosquito retires to some water to lay eggs, or eventually to die, these filariæ which have developed inside its body pass out by boring into the water, whence they are swallowed by man. Once inside the human stomach, the filariæ bore their way into the lymphatics, finally reaching their permanent abode in some distant lymph-vessel, where, as the *Filariæ Bancrofti*, they give rise to chyluria and elephantiasis, and breed, their progeny passing into the blood as before explained, till, released by the mosquito, they in their turn can complete their circle of development. Both Anopheles and Culex mosquitoes may act as hosts of *F. Bancrofti*. The following have been shown to act as hosts:—*C. pipiens*, *C. ciliaris*, *C. fatigans*, *P. costalis*, *Myzom. Rossii* and *Myzor. sinensis*.

* Bancroft: "On the Metamorphosis of the Young Form of Fil. Bancrofti in the Body of Culex ciliaris," *Proc. Roy. Soc. N. S. Wales*, 1900, xxiii. p. 48.

Filaria loa.—Very little is known of this parasite, although it is by no means uncommon on the West Coast of Africa. It chiefly affects the subcutaneous tissues, being possessed of considerable powers of locomotion. It is often found in the loose cellular tissue beneath the conjunctivæ, where it creates much irritation. Leuckart gives the length of this worm as from 30 to 40 mm., with the thickness of a fiddle-string. One end is pointed, the other blunt, the latter probably being the head, as it is provided with a prominent papilla, but no special armature. Nothing is known of its life-history, but Manson, from the fact that it had been present at a previous date in a negro in whose blood he afterwards found *F. diurna*, has suggested that *F. loa* may turn out to be the female parental form of *Microfilaria diurna*.

FIG. 119.—EMBRYO OF GUINEA-WORM (AFTER BASTIAN).

Filaria immitis has been found in a few cases in man; it lives chiefly in the right cavities of the heart and venous systems of dogs and wolves. The male measures 16 cm. in length and 0·9 mm. in breadth; the tail is slender and twisted like a corkscrew. The female measures 30 cm. in length and from 1 to 1·25 mm. in breadth; the posterior extremity terminates in a very thin point. The embryos of this nematode develop in the malpighian tubes of anopheles mosquitoes. They afterwards enter the general body cavity of the insect and pass towards the labium. These filariæ are most numerous in the blood of dogs at night.*

Filaria ozzardi.—The microfilarial forms have been found frequently in the blood of natives in British Guiana, but the adult forms only once. The larvæ measure 0·24 mm. and have no sheath. The caudal extremity is finely pointed. They appear in the peripheral blood at all times of the day. The male adult worm measures 38 mm. by 0·2 mm.; the female is 80 mm. in length and 0·22 mm. in breadth. The tail is bluntly truncated and slightly bulbous.† Recent observations indicate that this filaria is probably identical with *F. perstans*.

Filaria demarquayi.—It is doubtful whether the adult forms are known. A female has been described, differing but slightly from *F. ozzardi*. The larval forms have been found in the peripheral blood of natives in St. Vincent and the Brazils: they appear to be very similar to those of *F. ozzardi*. There is no periodicity, and the intermediary host is not known.

Filaria medinensis or Guinea-worm in its female adult stage lives beneath the surface of the body, preparatory to extruding its embryos through the skin into water. The adult male has only once been found; it apparently dies after copulation. The *filaria medinensis* is a parasite endemic in many parts of India, Persia, Arabia, Egypt, the West Coast of Africa, Demerara, the Brazils, and other tropical countries. The Guinea-worm disease is undoubtedly the same disease as the dracontiasis of Plutarch, and corresponds also with the Israelitish endemic affection described by Moses as due to fiery serpents. The curiously limited prevalence of this parasite in certain

* Bowlby: "Two Cases of Filaria immitis in Man," *Lancet*, 1889, vol. i. p. 786; *see also* Sambon: *Lancet*, 1902.

† Manson: "On Certain New Species of Nematode Occurring in America," *Brit. Med. Journal*, 1897, vol. ii. p. 1837.

districts was for many years inexplicable, until Fedschenko discovered the fact that a certain species of fresh-water cyclops, having apparently a very capricious distribution, is a necessary factor in the life-history of the filaria. Consequently, the distribution of the Guinea-worm is bound up with, and dependent on, the distribution of the particular species of fresh-water crustacean which, in reality, acts as its intermediate host.

Not only man, but oxen and some other animals, are affected with this filaria, or a parasite very closely allied to it. As yet, the female dracunculus alone is known with certainty, though Charles has described structures in connection with two female dracunculi which are suggestive of the male dracunculus *in coitu*. Immature specimens of Guinea-worm vary in length from a few inches to as many feet. The mature worm is a long, milky-white, slender, cylindrical organism, having a thickness of about $\frac{1}{10}$th of an inch, and not at all unlike a thick fiddle-string. Its actual length varies from 1 to 12 feet. The head of the worm is short and tapering, terminating in an oval irregular surface called the "cephalic shield." In the centre of this is a triangular buccal orifice, which leads to an alimentary canal, extending along the whole length of the creature, and ending blindly. Close to the buccal orifice are two papillæ, with six others at the circumference of the shield; these are generally regarded as sensory organs. The posterior end of the parasite terminates in a blunt point which is often bent, like a hook, towards the ventral surface. Nearly the whole of the worm is occupied by a long, tubular, and embryo-filled uterus. No trace of a vagina can be detected in the mature worm, though there is evidence to suggest that originally there was one. The emission of embryos appears to take place by the buccal orifice.

Like many other animal parasites, its presence in the tissues of man is but a portion of its life-history, and to complete its cycle of existence it requires to pass into the tissues of some other living organism. The worm, having gained access to man's body, probably in a larval form, lying in the body of the cyclops, bores its way into the tissues. When or where the sexes come together, and what are the subsequent steps in the development of the female, and what becomes of the male worm, are unknown. After an interval of from nine months to a year, a stage of maturity appears to be reached, as indicated by the presence of a worm many inches in length, embedded in the cellular tissue of the host, with an enormously developed uterus packed with millions of embryos. The embryo which is emitted from man is aquatic in habit, and to develop further needs to pass into water. In size the embryos measure $\frac{1}{50}$th by $\frac{1}{1000}$th of an inch. They are distinctly flattened, tapering towards the head end, and terminating posteriorly in a long, slender, sharply pointed tail (Fig. 119). They are very active, swimming about like a tadpole; they can be kept alive in moist earth or water for some twenty days. In water, if it meets its necessary intermediary host, the cyclops, the embryo filaria, penetrates the little crustacean, and in its body, in about five weeks, undergoes considerable development towards a more mature condition. Lying in the body of the cyclops, the filaria waits an opportunity of being conveyed in drinking water to the stomach of its human host or of some other animal, whence it can continue its cycle of existence, as already described.*

Tricocephalus dispar, or the "whip-worm," is possibly the most common of all intestinal parasites affecting man in the tropics, and not infrequently met with in Europe. Its eggs are so characteristic (Fig. 3, Plate XII.) that having once seen them it is not possible to mistake them

* Leiper: "The Etiology and Prophylaxis of Dracontiasis," *Brit. Med. Journal*, 1907, vol. i. p. 129.

for any other. Their usual size is 36 μ in length by 26 μ in breadth ; in colour they vary from a yellowish-brown to red. The eggs are commonly voided by the worm into the bowel, and when discharged from the bowel the embryo is not differentiated within them. Its development remains in abeyance until the egg is carried into water or other damp medium. This happening, development proceeds, and on the egg being swallowed by man in drinking water, the embryo is liberated in the alimentary canal, where it attaches itself to the mucous membrane of the cæcum by means of the whiplash-like anterior part of its body (Fig. 120). The development of this worm is slow, probably being rarely completed within the year.

The intermediate host is unknown, but the experiments of Davaine render it probable that infection takes place in a direct manner some time

Fig. 120.—Tricocephalus dispar.

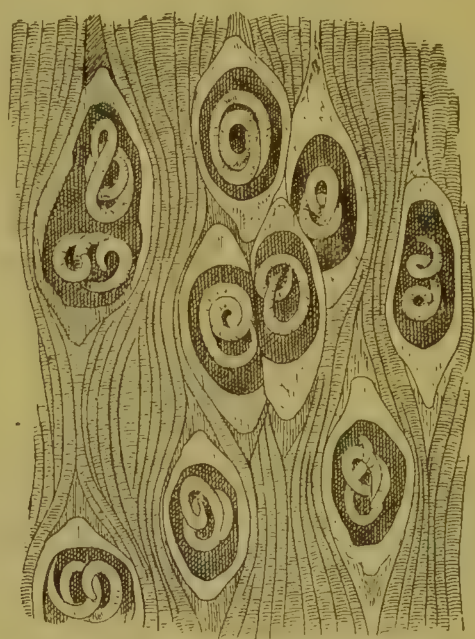


Fig. 121.—Muscle containing Trichinæ spirales.

after the eggs have escaped the human bearer. The embryos will live for many years in the free eggs, even if exposed to dryness.*

Trichina spiralis.—The larval forms are commonly spoken of as flesh-worms. The adult is a small worm, varying from $\frac{1}{18}$th to $\frac{1}{8}$th of an inch in length, which not only attacks man, but also pigs and other animals, producing the disease known as trichinosis. In this disease, the muscles present a number of ovoid cysts, about $\frac{1}{70}$th of an inch in length, just visible to the naked eye, within each of which is coiled an immature trichina, not much more than $\frac{1}{40}$th of an inch long (Fig. 121). If by chance the tissue or muscle containing the capsules be eaten, the capsule is dissolved, and the young worm is set free. This rapidly develops, and breeds so rapidly that within a week the embryos of the trichina, by burrowing through the intestinal walls, are able to find their way into all parts of the consumer's body, especially the muscles, in which they soon get encapsuled, to go through the same history again. When trichinosis occurs in man, it is generally due to the eating of the imperfectly cooked flesh of pigs suffering from the disease. It is somewhat common in Germany, where sausages, hams, and pork are more often eaten than in this

* Boycott and French : "The Prevalence of Tricocephalus Dispar," *Journal of Hygiene*, July 1905, p. 274.

country. The symptoms of trichinosis are sickness, prostration, fever, and muscular pains. The mortality is often slight, but occasionally very high.

Rats, especially the sewer rat or *Mus decumanus*, are the normal hosts of trichina spiralis. These animals infect others of their own family and also transmit trichinosis to other species by whom they are eaten, such as pigs, dogs, cats, bears, foxes, and martens. Man's chief source of nfection is insufficiently cooked swine's flesh.

Ankylostoma duodenale, sometimes called *Dochmius duodenalis*. This is a short worm which attaches itself, often in large numbers, to the villi of the small intestine. It is very widely distributed, being found in Europe, Egypt, Zanzibar, Gold Coast, West Indies, Brazil, Peru, Bolivia, Assam, Lower Bengal, Borneo, Java, and Australia. It is the cause of the pathological condition known as ankylostomiasis, marked by a serious and often fatal form of anæmia, the result of the large amount of blood abstracted by the parasite.

This entozoon is whitish in colour when empty, but reddish brown when filled with blood. Its length is from 8 to 18 mm., with a breadth of about 1 mm. Both the males and females (Fig. 122) are cylindrical with conical pointed heads. The females have also a pointed posterior, but the males are readily distinguished by having in this situation a peculiar bell-shaped *bursa copulatrix*. The mouth is provided with four strong, claw-like teeth.

The adult animal lives generally in the jejunum or duodenum, the eggs (Fig. 4, Plate XII.) being expelled with the fæces, in which they can be readily detected by microscopical examination. The embryo is never found developed within the eggs in the fæces up to the time of their evacuation, but appears, on being discharged from the intestine, to undergo its primary development in wet soil, being much favoured by a high temperature and exposure to air.

FIG. 122. — ANKYLOSTOMA DUODENALE (AFTER SONSINO). *a*, Male; *b*, Female; *c*, Embryo.

The young worm is very different from the adult, and shows a typical rhabditic form, characterised by a spindle-shaped œsophagus ending in a chitinous bulb provided with three chitinous ridges, and an abruptly pointed tail. Under favourable conditions of warmth and moisture, the young larvæ rapidly undergo development, marked by an incomplete kind of moulting, which gives them the appearance of being enclosed in a kind of case. While four to eight days are needed to hatch the eggs at 16° C., another three to four weeks are required for the larvæ to reach the encapsuled stage. This time may be prolonged if at intervals they be exposed to a lower temperature. Once encapsuled, the larva has reached the infective stage, and, outside the human body, never passes beyond this stage, in which

there are also absent all signs of sexual difference or mode of reproduction. In addition to an optimum temperature of about 25° C., moisture, short of actual immersion, and air are necessary for the development of the eggs and of the larvæ. On the other hand, exposure to direct or even diffuse sunlight is sufficient to retard development and even kill within forty-eight hours. There is evidence to show the longevity, under favourable circumstances, of the eggs to be six weeks and of the larvæ some six months; but it is not improbable that obscure conditions of soil, apart from temperature and dampness, influence development.*

If the ova or freshly developed larvæ are swallowed by man, the adult worm does not develop in the intestine; on the other hand, if the encapsuled or fully developed larvæ be swallowed, adult parasites develop and their ova appear in the fæces of the host in about a month. The path of infection is not, however, limited to the month, though probably the most frequent. Looss † and Pieri's experiments, also Bentley's observations in Assam and those of Boycott and Haldane at Dolcoath show that infection may result by direct passage of the fully developed larval forms through the skin, which not infrequently may be inflamed and the seat of furuncles as the local effect of infection. In the light of these facts, it is intelligible how miners, bricklayers, agriculturists, and others handling damp and infected soil may get infection through the skin as well as by the mouth, though the risk of infection by this latter channel during such work must be great. F. Smith ‡ has suggested that in Sierra Leone infection by ankylostoma may possibly be by a fly such as *Stethopathus ocellatus*. The point raised is interesting but, at present, lacking in precise evidence.

From what we know of the life-history of this parasite it is evident that prevention demands attention to rules applying both to the individual and to the community. The principal personal rules will be careful washing of the hands and nails before eating, whenever mud has been handled; and the drinking of only filtered or boiled water. For the community, care needs to be taken that, in endemic areas, indiscriminate defæcation over the country is not practised; suitable disinfection of the infected dejecta should be insisted on, and simple precepts of prevention, suited to the understandings of native people in whom this parasite so extensively prevails, promulgated.

In America, ankylostomiasis appears to be due to a new species, *Uncinaria Americana*, first described by Stiles in 1902.§ It is shorter and more slender than the old-world hook-worm. The male measures 8 mm. in length by 0·3 mm in width; the female is 10 mm. long and 0·4 mm. wide. The buccal cavity is smaller, with two prominent ventral semilunar plates, instead of four ventral hook-like teeth. In the female, the vulva is near the equator of the anterior part of the body. The eggs of the American species are larger than those of A. duodenale, measuring 0·7 μ in length by 0·4 μ in breadth. The life-history of this variety is not known, but it probably is not materially different from that of the Eurpean ankylostome.

* Boycott and Haldane: "Ankylostomiasis," *Journal of Hygiene*, vol. iii. No. 1, *also* vol. iv. No. 1; *see also* Haldane's Report to Home Secretary on an Outbreak of Ankylostomiasis in a Cornish Mine, 1903, and Report on Ankylostomiasis in Westphalian Collieries, 1904.

† Looss: *The Anatomy and Life-history of Agchylostoma duodenale.* Translated from the German. Cairo, 1905. Ministry of Public Instruction.

‡ F. Smith: "Ankylostomiasis in Sierra Leone," *Jour. Roy. Army Med. Corps*, vol. iv. pp. 12 and 189.

§ Stiles: Report on Prevalence and Distribution of Hook-worm Disease in the United States, Washington, 1903.

PLATE XII.

Ova of Parasites

Ascaris lumbricoides.—This is the common round worm, being in general appearance very like the ordinary earthworm. It is pinkish in colour, tapering at each end, and measuring some 6 inches long in the case of the males, and 12 inches in the case of the females. In man it usually infests the small intestine, where it gives off large numbers of eggs. These, though colourless when within the worm, are usually brown when seen within fæces, owing to the action of the bile upon the outer shell, which is, moreover, characteristically nodulated (Fig. 2, Plate XII). In shape they are not unlike a barrel, and measure 65 μ long and about 45 μ broad. The inner layer of the shell is transparent, colourless, and rather thick, with a multiple outline. At a medium temperature, the embryo forms in thirty-five days. This never leaves the egg in the open. Davaine proved that the larvæ hatch out in the intestine of the rat, but are again expelled with the fæces. Epstein,* experimenting on three children, showed that direct infection with embryo-containing eggs is beyond doubt, and that the development of the eggs takes place more rapidly in the fæces when there is free access of air, light, and a sufficiency of moisture. Infection apparently may be by water, by soil, or direct from man. Pigs being infested by this worm, the water from streams or pools in the neighbourhood of pigsties becomes a dangerous source of infection, if employed for domestic purposes.

The large lumbricoid worm of the horse is an entirely distinct species.

Ascaris mystax.—This nematode is probably identical with the *A. alata* of Bellingham. Its stages of growth have been traced by Leuckart in the cat, in whose stomach specimens of the larvæ were found measuring only $\frac{1}{32}$nd of an inch. From Hering's observations, it would seem probable that a period of three weeks is amply sufficient for the production of sexual maturity after the larvæ have gained access to the body of the ultimate bearer. The bearer may be either man himself, or more commonly a cat, dog, or some carnivorous animal.

Oxyuris vermicularis.—This is the common thread-worm, a well-known human parasite occurring in large numbers in the cæcum and upper part of the colon. The female is about $\frac{1}{2}$ an inch long, and the male $\frac{1}{4}$ of an inch. The female gives off enormous numbers of colourless, oval, unsymmetrical eggs, each being 50 μ in length and about half as broad. These eggs have a rather thin shell with a double outline (Fig. 1, Plate XII.), and may contain a well-developed embryo, which, at first tadpole-like, rapidly assumes, under suitable conditions of heat and moisture, a vermiform character. For the purposes of infection it is alone necessary that the eggs of the worm be conveyed to the mouth and swallowed. Their previous immersion in water for any length of time secures their destruction, by the bursting of the shell consequent upon endosmosis. The eggs are conveyed to the mouth in various ways. Ordinarily children become infested by biting their nails, beneath the margins of which the eggs lie concealed. Occasionally, the eggs are swallowed by accident during sleep, or the whole parasite may be conveyed to the mouth in a similar manner. In whatever manner they may have been carried to the bearer, when once the eggs have gained access to the stomach, their shells are dissolved by the gastric juice, and the larvæ liberated. In the upper intestine, the larvæ grow rapidly; here they undergo one or more changes of skin, acquiring sexual maturity within a period of less than a month. Improperly cooked or raw vegetables and water are the vehicles by which they directly reach man from outside.

* Epstein: "Über die Übertrag. die Menschlich. Spulw.," *Jahrb. f. Krankenheilde. N. F.*, 1892, xxxiii. No. 3.

ACANTHOCEPHALA.

These are gutless worms somewhat like nematodes, carrying at their anterior end a retractile rostrum beset with hooks. The sexes are separate, and the males are readily distinguished by being both smaller and thinner than the females. The size is variable according to the species, but it varies from 5 to 10 mm. up to 30 cm. In their adult condition these worms live only in vertebrates; but during their larval stage they are often parasitic in invertebrate animals. The eggs are fertilised in the body cavity, and in this position go through their development to the formation of an embryo. Completely developed eggs are fusiform, with three shells. The subsequent metamorphosis of these worms is somewhat complicated; the eggs are passed into water, where they are consumed by a crustacean or insect. In these intermediary hosts, the larvæ hatch out in the form of an elongated, somewhat bent body, at the anterior end of which is a crown of spines or hooks; the hinder end is pointed. In the middle of the larval body, the echinorhynchus originates and develops; the whole of the changes appear to take place within the intermediary host. On reaching its terminal host, the parasite attains the adult stage. In some cases, a second intermediate host seems to be needed.

Species of acanthocephala in man are rare; the best known is *Echinorhynchus hominis*, which is a worm some 6 mm. long having a spherical head beset with twelve transverse rows of hooks. Little is known of its life-history. Another species, *E. gigas*, is common in the pig, and has been stated to have been found in man in Russia. Its intermediate host is probably the cockchafer, which, according to Schneider, is occasionally eaten raw by some human beings. Both Kaiser and Stiles give the golden beetle also as an intermediate host for this parasite.*

HIRUDINEA.

These annelids differ in many respects from the typical members of the group. They have long flat bodies without the parapodia that are so characteristic of all forms of the annelida. There is an anterior and sometimes a posterior sucker. The mouth is located at the anterior end, while the anus lies dorsally above the posterior sucker. The muscular system is much developed in these worms, and the body is fleshy and segmented. The type of this family is the leech.

Almost all the hirudinea are hermaphrodite and copulate reciprocally. The leeches deposit so-called cocoons, which are small barrel-shaped bodies surrounded by a thick shell, containing a number of eggs in a mass of albuminous material. A number of suctorial annelids attack man in such a way as to deserve the title of parasites. In this category come the ordinary leeches, besides numerous aberrant forms which have been only imperfectly described.

Limnatis nilotica.—This, the common horse leech, is found in nearly all parts of Europe, in Egypt, and throughout North Africa. This species often attacks man in warm climates, attaching itself to the mucous surfaces of the nose and pharynx, and even entering the larynx and air passages. Men are much debilitated by them at times; and in the event of

* Braun: *The Animal Parasites of Man.* Translated from the German by P. Falcke and edited by Sambon and Theobald. London, 1906, p. 344.

their entering the air passages, death by asphyxia may ensue. There is no doubt that these leeches enter the mouth by means of foul drinking water.

This species is about 10 cm. in length, becoming very pointed towards the fore part. Its colour is brown or greenish on the back, with usually six longitudinal rows of black dots. The abdomen is dark. This leech, like our own *H. medicinalis*, lives in swamp and ponds overgrown with plants; the cocoons are deposited in the soil at the sides.

Hæmadipsa ceylonica or *Sanguisuga tagalla* is the land leech of Ceylon and other tropical countries, where it lives in woods and damp undergrowths. It is about 3 cm. in length and a little thicker than an ordinary knitting needle, but extremely active. It lies among the leaves and grass, and attacks any man or beast which passes near it. Similar land leeches are found in Java, the Philippines, in the Himalayas, Africa, Australia, and Chili. All varieties appear to possess great suctorial powers, and if disregarded, by producing repeated hæmorrhages, may bring about a state of great debility.

ARTHROPODA.

These jointed-limbed creatures are bilaterally symmetrical segmented animals which are covered with a thick cuticle, and provided with a pair of jointed appendages on every segment. The appendages on the head are primitively locomotive organs, but transformed into mouth parts and feelers, those on the thorax and abdomen retain usually their ambulatory functions. In their general organisation, the arthropoda resemble the segmented worms, and are divided into five groups, namely, the crustacea, the protracheata, the myriapoda, the arachnoidea, and the insecta. Only the last two groups are of interest to us here, as containing forms parasitic to man.

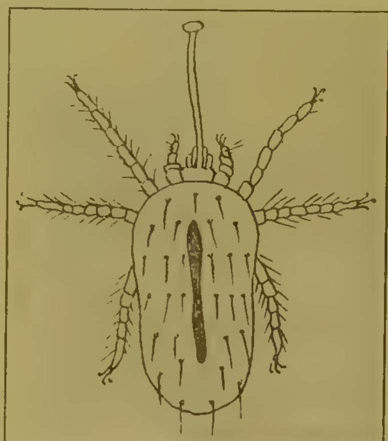


FIG. 123.—LEPTUS AUTUMNALIS.

Leptus autumnalis is a small arachnoid which attacks the skin of man in the autumn, producing an erythema, often accompanied by slight fever (Fig. 123). A number of Leptus occur abroad and attack man much in the same way as L. autumnalis does in this country. The more notable of these are *Trombidium tlalsahuate* occurring in Mexico, and *Tetranychus molestissimus* found in Argentina and Uruguay. Both these mites attack man and animals, giving rise to much discomfort. Another acarine allied closely to the foregoing is the Kedani mite (Fig. 124) of Japan, which is suspected of causing a serious illness, called "river fever." If the mite is not removed from the skin, or if the spot attacked is injured by scratching, a papule ensues, leading to the formation of a septic sore which produces fever.* More recently, Ogata † claims to have detected an infecting sporozoon, conveyed by these mites.

A large and important family among the acarina are the **Ticks**. These blood-suckers are not only important as actual parasites, but also on account

* Tanaka: "Über Ætiol. u. Path. d. Kedani-krankheiten," *Centr. f. Bakt. u. Parasitkde*, 1899, xxvi, p. 432.

† Ogata: "Vorläufige Mittheilung u. d. Ætiol. d. Tsutsugamushi Krankheit," *Deutsche Med. Woesch.*, 1906, pp. 1828, 1868.

of the fact that they are the active agents in carrying various diseases among animals and men. The life-history of a tick is briefly as follows :—The female deposits her eggs in masses on the ground, and then gradually shrivels up and dies. The favourite place for ovi-deposition is on grass or coarse herbage. The egg-stage varies from eight to twenty-two weeks, and then gives rise to the larval form. These larvæ are six-legged and soon crawl up grasses and plants, waiting to become attached to some passing host. The larval ticks feed upon the blood of the host and when repleted fall to the ground. Here they moult and change to the nymph or pupal stage, which has four pairs of legs. The pupa acts just as the larva, crawling up grass and there waiting to regain a host. Having done so and gorged blood, the nymph falls to the ground and remains there a variable time, sometimes as long as three months. It then moults and becomes an adult male or female tick, which, regaining a host, feeds on its blood and then repeats the cycle. Ticks may

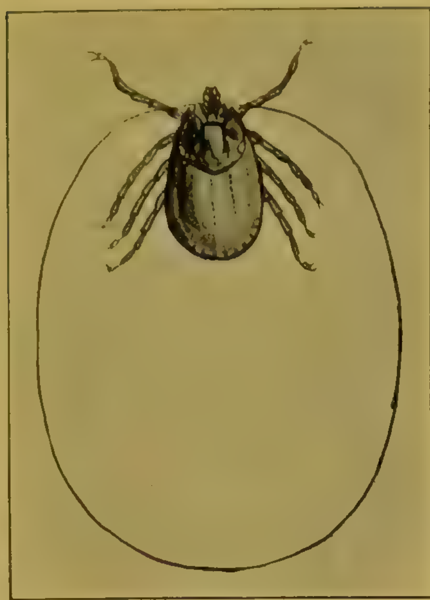
FIG. 124.—THE KEDANI OR AKAMUSHI MITE (AFTER TANAKA).

live a long time away from the host, provided they have moisture. There seems to be no pressing necessity for a tick to secure a host, for even if starved and growth be arrested, the longevity is marked ; on the other hand, feeding on a host appears to be essential for growth and exuviation, and under these favourable conditions life is often brief. Although in the majority of species of ticks, each individual must find a host three times in the course of its existence, namely, in its larval, nymphal and adult stages, there are notable exceptions to this rule. Thus, *Rhipicephalus annulatus* effects both moults upon one host ; *R. bursa* makes its first moult on the host and its second on the ground, thus needing a host twice ; *R. appendiculatus* effects both moults on the ground, thus needing three hosts. Alternative stages are exemplified by *Hyalomma hebræum*, which is apparently parasitic only in adult condition, while, in the case of *Ornithodoros moubata*, the larval stage is passed within the egg-shell, so that the nymph in reality emerges from the egg. The life-history of the ticks is represented in Plate XIII.

The ticks may be distinguished from other acari (*a*) by the presence of a median probe, beset with recurved teeth, which projects forward beneath the mouth and between the palpi ; (*b*) by the position of a conspicuous

PLATE XIII

Larva of "Brown" Tick. × 4.

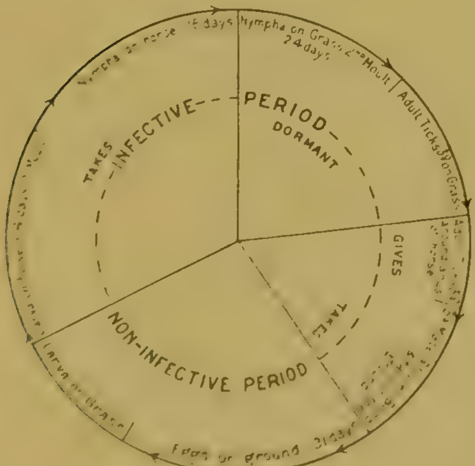


Female of "Brown" Tick, before and after feeding. × 4.

Nympha of "Brown" Tick. × 4.

Male of "Brown" Tick, before feeding. × 4.

Male of "Brown" Tick, after feeding. × 4.



Life Cycle of Tick with Two Hosts.

Life Cycle of Tick with Three Hosts.

spiracular area, usually behind the base of the last leg on each side, and upon which opens the orifice of the tracheal system. The ticks are divided into two groups, the argasinæ and the ixodinæ. The former have no dorsal shield and the capitulum is concealed from above; the legs are nearly equal in length, while the males are usually smaller than the females. The members of this family are nearly all house-ticks, and more commonly parasitic on poultry than on cattle or other mammals. They hide in crevices during the day, and come out at night to feed. The family ixodinæ have a dorsal shield and the capitulum is exposed from above. In the males, the dorsal integument is chitinised throughout, and no porous areas on the capitulum. In the females, the dorsal surface has a small chitinous plate anteriorly; on the capitulum are two porous areas. The legs are unequal in length, with the usual six segments, known as coxa, trochanter, femur, patella, tibia, tarsus, and two false segments or pads. The shields are well defined. The ixodinæ are divided into two groups, (*a*) the ixodæ, having a long proboscis or even longer than the palpi; (*b*) the rhipicephalidæ with short palpi and short proboscis. The more important of the ticks are the following:—

Hyalomma hebræum.—This is a very large tick common in Egypt and other parts of Africa. The male is 8 mm. long and from 4 to 5 mm. wide. The female may be as much as 24 mm. long and 15 mm. in breadth, when gorged with blood. It infests large and small animals as well as man. In South Africa, it is known as the Bont tick, where it causes much sickness among sheep and goats. The male has a white dorsal plate, variegated with brown, a pair of short stripes in front but three stripes behind. The dorsal plate is finely punctured. In the female, the plate is brown, and heavily punctured on the lateral area. Recently, Skinner * has suggested that this tick might be a vehicular host for carrying the plague bacillus, not only from animal to animal, but from rodents to man. There appears to be little evidence in support of this view.

Rhipicephalus annulatus.—This tick is widely distributed in America, Texas, and Queensland, being the medium by which Texas or red-water fever is distributed among cattle. The male is 2·5 mm. long; the dorsal plate is oval, brown to black in colour with a pale margin. The adult female is 3 mm. long when not distended, but when gorged may measure 13 mm. long. The dorsal plate is small, longer than wide, and having its edges parallel anteriorly. The larval forms of this tick, if fed on an infected host, may transmit the piroplasma bigeminum to other hosts in the nymph or adult stages. This tick can effect both moults upon one host.

Rhipicephalus appendiculatus is a tick related closely to the foregoing. It is common in South Africa, where it is known as the "brown tick," and associated with the dissemination of the piroplasma parvum, affecting cattle in those regions. Larvæ fed on infected hosts can infect other hosts in the nymph stage, and fed on infected blood in the nymph form can infect other hosts as adults. These ticks are 4 mm. long and 2·6 mm. wide; in the males, the dorsal plate does not quite cover the body laterally; reddish brown with many small close-set punctures, with eleven narrow festoons, the median being continued into a conical caudal process. In front of the festoons are three wide, short, longitudinal grooves. Ventral surface is nearly hairless. The female has an oval dorsal plate with sinuous margins, the festoons are similar to those on male. This tick needs a host for each stage of its existence. *R. simus* is a closely allied tick, differing

* Skinner: "Plague and the Geographical Distribution of Rats," *Brit. Med. Journal*, 1905, vol. i. p. 994; vol. ii. pp. 622, 926, and 1453.

from the foregoing mainly in the fact that the punctures are coarser along the marginal groove, while the festoons are unpunctured. This tick is known in South Africa as the "black-pitted" tick, and, like R. appendiculatus, infects cattle with "coast fever." Another species, difficult to detect from these two others, is *R. bursa*, common all over Africa, the West Indies, and Southern Europe. In Europe it conveys piroplasma ovis, the cause of "heart-water" in sheep. In this tick, the punctures are numerous, being small, equal and closely set. The median groove on the dorsal plate is short, with two depressions on each side of it.

Dermacentor reticulatus.—This tick is common in the Western States of North America and is believed to be the means of transmitting the infection of Rocky Mountain fever.

The male, which measures 5 mm. in length and 3·5 mm. in breadth, has a brown and white dorsal surface, the posterior area is marked with nine large brown blotches, the white areas between the blotches being speckled with brown over the punctures. The fourth coxæ are enormously enlarged.

Fig. 125.—Dermacentor reticulatus. Dorsal Surface of an undistended Female.

Fig. 126.—Ornithodoros moubata. Dorsal Surface of Female.

When distended, the female may measure as much as 16 mm. by 10 mm. The anterior chitinous plate is white, with two brown stripes over the cervical grooves and three spots between; the posterior area is brown with a marginal groove, three longitudinal grooves and festooned edge. The coxæ are spined as in the male (Fig. 125). This tick is widely distributed in Europe, Asia, and America. According to Nocard and Motas, it is the carrier of piroplasma canis in Europe.

Hæmaphysalis leachi is a tick infesting the dog and the apparent disseminator of canine piroplasmosis in various parts of South Africa. In the male, the dorsal plate is yellowish red, covered with many fine punctuations, with marginal groove and eleven posterior festoons. Length 3 mm., by 1·5 mm. wide. In the female, the dorsal plate is a long oval; the coxæ of the legs are spined as in the male, but less strongly. When distended, the female measures 9 mm. by 5 mm.

Argas reflexus is the so-called marginated tick of Europe. It is of a yellow colour with yellowish-white legs. It averages 4 mm. long in the male and 8 mm. in the female. Its chief home is in dovecotes, where it infests pigeons, but it frequently feeds on man, giving rise to serious symptoms, especially in children.

Argas persicus is another tick common in pigeons and fowls, especially in Persia and other parts of Central Asia. Its bite is much dreaded. There is some probability that this tick may transmit a form of fever to Europeans from natives. It is apparently identical with a parasite of fowls and ducks, known as the " wampan " in South Africa. The body of this tick is oval in outline, and yellowish or red in colour. The dorsal surface is rugose and shagreened, the marginal sculpturing being formed of irregular oblong areas each with a circular pit, and arranged radially to the centre of the dorsum.

Ornithodoros moubata.—This tick was observed by Dutton and Todd * in the Congo Free State to be the means of transmitting the spirochæte of relapsing fever from man to man. The female measures 12 mm. by 7 mm. when gorged; the male measures 3 mm. in length and 2 mm. in breadth. This tick has an ovate body, a little wider behind than in front; the colour is a greenish brown. The integument is studded with small tubercles and exhibits on the dorsal surface three pairs of longitudinal grooves, each arising from a fovea and running obliquely inwards and backwards; also with two short transverse grooves towards the posterior end. The ventral surface is marked by a deep pre-anal groove, and behind it three pairs of longitudinal depressions. This tick has no eyes, and differs from other argasinæ in passing the whole of its larval stage inside the egg (Fig. 126). There is evidence to suggest that the transmission of infection by this tick is not merely mechanical, but that some developmental process is carried on in the tick, as in at least one experiment the spirochætes were transmitted by the bites of young ticks newly hatched from eggs laid by infected parents. The eggs of the Ornithodoros moubata adhere to each other when laid, and look, under a low power, not unlike bunches of glistening golden-brown grapes. Their shape is ovoid, the average dimensions being 880 μ by 776 μ. In sandy soil, the eggs may be deposited either on or under the surface. Under a mean temperature of 25° C. and 72 per cent. of humidity, the eggs take but twenty days to hatch. The hexapod larva normally passes its complete stage in the egg-shell, and when ecdysis finally takes place, the nymph throws off egg-shell and larval-cast together. The newly hatched nymphs average 1 mm. The nymphs attain full size of 5 mm. in two months, undergoing three moults before becoming adult ticks. The life of these ticks is unknown, but they appear to be infective and capable of existing with little or no food for quite seven weeks.

Among the *tyroglyphidæ* and *glyciphagi* are numerous mites common in sugar and flour. Practically none of these are true human parasites except *Glyciphagus buski*, which is said to be the cause of a pustular disease known as craw-craw, prevalent among natives in Sierra Leone. A closely allied species, *Rhizoglyphus parasiticus*, is the cause of trouble on the feet of Indian coolies working in the tea gardens of Assam. These acari have a grey to greenish brown body; eyes are absent, and the legs have five segments terminating in a claw. Males measure 0·2 mm. in length and the females about 0·25 mm.†

Acarus scabiei, or human itch insect, has been described under a number of synonyms; it is probable that most of the so-called species infesting our domestic animals, as well as that called the Norway itch insect, are mere varieties of the common species (Fig. 127). The burrowing of the insect causes much itching and some rash. It is the female only which

* Dutton and Todd: *On the Nature of Human Tick-fever in the Congo Free State*, Mem. XVII., Liverpool School of Tropical Medicine.

† Dalgetty: "Water itch," *Journal of Tropical Medicine*, 1901, vol. iv. p. 73.

thus penetrates the skin and causes the characteristic symptoms of the disease known as scabies ; for burrowing beneath the cuticle, she lays her eggs at the end of the burrow, where they hatch, and the young insects then commence to burrow afresh in other directions.

In France, the face mite, or *Demodex folliculorum*, is a fruitful source of personal disfiguration. A variety infests the dog. According to some statements, demodex occurs in 50 per cent. of mankind ; they survive the death of their hosts by several days.

Man is occasionally the host of sexually incomplete forms of arachnoidea. These are the "tongue-worms" belonging to the order *linguatulidæ*. The more important are the following :—

Pentastomum denticulatum.—This is the sexually incomplete state of the mature form known as *P. tænioides*, which resides in the nasal chambers of the dog and other animals. In the larval form, as *P. denticu-*

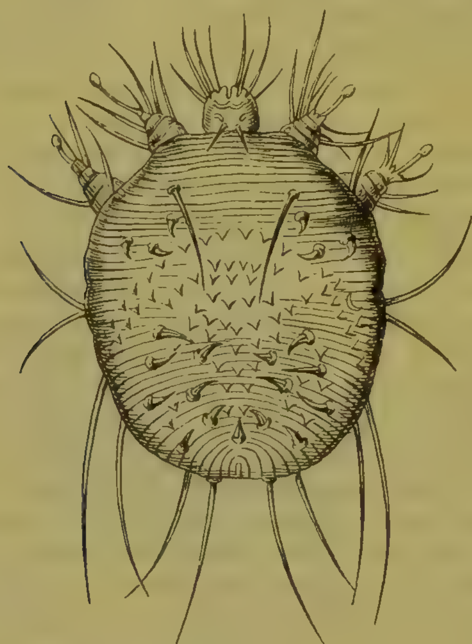


FIG. 127.—ACARUS SCABIEI.

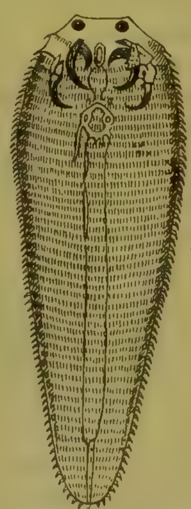


FIG. 128.—PENTASTOMUM DENTICULATUM (AFTER LEUCKART).

latum, it infests the liver and lungs of man. Formerly, these two pentastomidæ were thought to be distinct, until Leuckart succeeded in rearing the so-called *P. denticulatum* in the intestine of the rabbit from the eggs of *P. tænioides*, and traced the development of the young *P. denticulatum* into the adult *P. tænioides* by placing the embryo in the nasal cavity of the dog. The life-history of this parasite appears to be briefly this. The young form inhabits cysts in the liver and lung of herbivorous mammals ; presently the young animal breaks through its cyst and makes its way into the body cavity, after causing considerable injury to the tissues during its transit, and occasionally even causing the death of its host. Sometimes it wanders again into the viscera or into the lymphatics. If the body of its host be devoured by a dog or some carnivorous animal, the young *Pentastomum*, if not already encysted, finds its way directly through the nares into the olfactory cavity, where it attains sexual maturity. The *P. denticulatum* has often been found in the liver and lungs of man in various parts of Europe ; its organs of locomotion are hooks and spines, which are developed towards the close of the resting stage, and finally laid aside after they have served their purpose.*

* Shipley : "An Attempt to Revise the Family Linguatulidæ," *Archiv. de Parasitologie*, 1898, i. p. 52.

Pentastomum constrictum.—This parasite is not uncommon in Egypt, the Sudan, and West Coast of Africa. It is the larval form of an arachnid, of which the adult stage is still unknown. It has a white, annulated, cylindrical body, with a rounded anterior, but rather conical posterior end. The ventral surface is flattened, the entire parasite measuring about 15 mm. in length by less than 3 mm. in breadth. It has four foot-claws near the mouth. The elongated abdomen displays twenty-three rings, placed at tolerably regular intervals. It differs from *P. denticulatum*, which we have seen to be the larval form of *P. tænioides*, in not possessing integumentary spines, and in being a much larger parasite. It is found coiled upon itself in a cyst, situated generally near the surface of the liver, in such a way as to be perceived through the fibrous capsule of the organ.

Fig. 129.—Pentastomum constrictum (after Aitken).

Among the insects, we find instances of so-called free parasitism, partial parasitism, and true parasitism affecting man. As examples of free parasitic insects we may quote the following :—

Pediculus capitis or head-louse is spread all over the globe. In rare cases it bores itself deep into the epidermis, and has been described as present

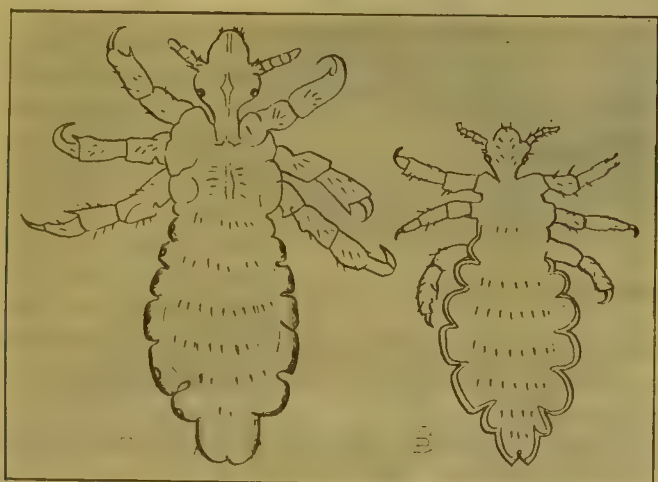


Fig. 130.—A, Pediculus capitis. B, Pediculus vestimenti. ×16.

in open ulcers. The eggs are pear-shaped and attached to the hairs near the roots by means of a clasping collar. They hatch in about seven days. The colour of this louse varies with that of its host. Each female lays fifty eggs.

Pediculus vestimenti is shown in Fig. 130; this parasite differs from the preceding by having longer antennæ, also the abdomen is broader than the thorax. Each female lays seventy eggs.

Phthirius inguinalis.—Although this louse lives on all hairy parts of the body, except the scalp, its favourite abode is the pubic region. This species is very fecundive, and is communicated more freely from man to man than any other lice. The eggs are laid singly, as a rule, being attached to the hairs near the free end. It is rare to find this parasite on other than white races (Fig. 131).

Among the bugs which often give trouble to man and infest human

habitations may be mentioned *Cimex lectularius* or common bed-bug of this country; the *Conorhinus sanguisuga* or big bed-bug of Texas and Mexico; and the *Reduvius personatus* or masked bug of the United States. The swelling and irritation caused by this insect is often severe. The larva of this bug is carnivorous, while the adult is very active on the wing. Patton's observations indicate that *Cimex rotundatus* or the Indian bed-bug is the means by which man contracts Kala-azar; C. rotundatus is probably identical with the bed-bug of Burmah or C. macrocephalus.

The diptera or order of two-winged flies present a large number of species which are of importance, some being actually parasitic to man, while others are associated intimately in conveying other parasites to and from human beings and animals. The order is divided into three sub-orders, namely:—(1) *Aphaniptera* or apterous insects provided with a piercing mouth, flat body, small head, short, thick antennæ lying in pits in the head, eyes absent or represented by two ocelli, thorax of three segments, abdomen of nine segments, legs adapted for jumping, and the mouth parts consisting of maxillæ, mandibles and labium. The aphaniptera are represented by the fleas. (2) *Orthorrhapha.*—This sub-order has larvæ with a distinct head, and pupæ either free or in a larval skin or puparium. It is divided into two sections, namely, nematocera and brachycera. The nematocerous section have long, filiform, six-jointed antennæ and three to five-jointed palpi. This section includes the midges, gnats, mosquitoes, sand-flies, and daddy-long-legs. The other, or brachycerous section, has short three-jointed antennæ and short two-jointed palpi; in this group are the various gad-flies. (3) *Cyclorrhapha* or small flies with three-segmented antennæ bearing a non-terminal bristle. This sub-order includes the dung-flies, flesh-flies, house-flies and tsetse-flies.

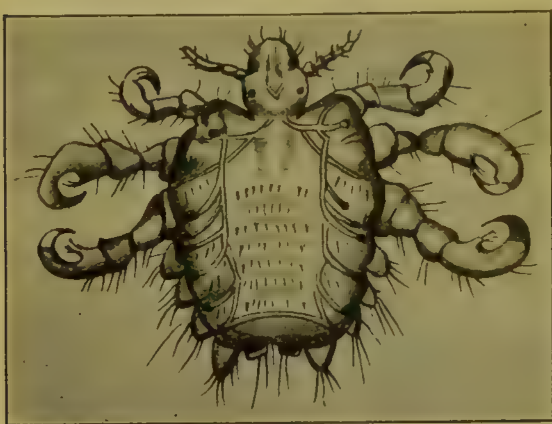
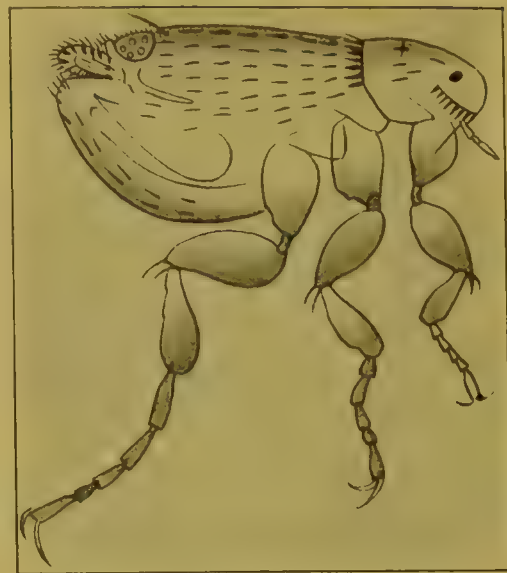


FIG. 131.—PHTHIRIUS INGUINALIS. × 25.

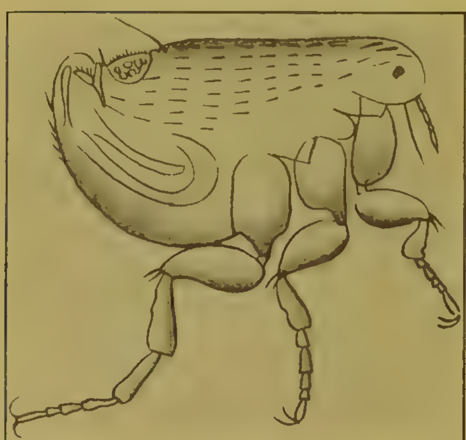
The **Fleas** have the body flattened laterally and present for notice head, thorax, and abdomen. The shape of the head varies in different species. It is united behind firmly to the thorax, and attached antro-ventrally are the mouth parts, characterised in some species with a row of large bristles. Over the surface of the head are often a number of bristles. The thorax consists of three segments jointed together, and very freely movable on one another. Numerous bristles, arranged in one or two vertical rows, are found on each segment of the thorax. To each segment a pair of legs is attached; to the distal extremity of the last segment two claws are attached, while the arrangement of bristles on the various leg segments constitutes an important feature for recognising species. The abdomen is made up of nine segments, each segment consisting of a dorsal portion or tergite, and a ventral portion or sternite. One or two vertical rows of bristles are present on each of the anterior tergites, while only a single row is found on some of the sternites. If the dorsal margin of the abdomen be followed backwards, the observer will find one or more bristles anterior to and over-hanging an oval organ, which is the "pygidium." Immediately posterior to the pygidium lie the genital organs.

PLATE XIV

PULEX IRRITANS. ♂

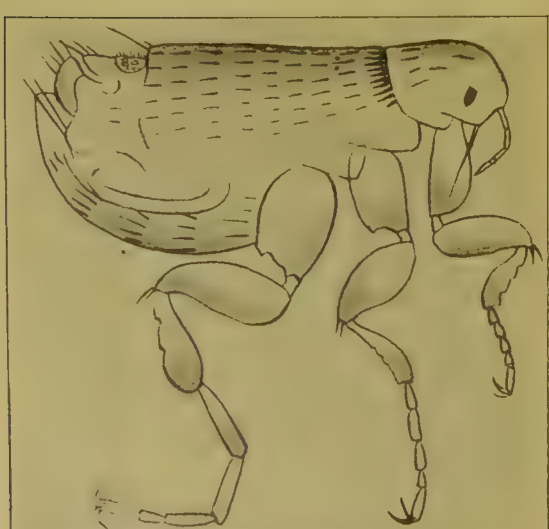


PULEX FELIS. ♂



PULEX CHEOPIS. ♂

SARCOPSYLLA GALLINACEA. ♂



CERATOPHYLLUS FASCIATUS. ♂

CTENOPSYLLA MUSCULI. ♂

The male flea is usually smaller than the female; the shape of the abdomen differs from that of the female, and within the male abdomen are curved chitinous plates connected with the sexual organs which are wanting in the female. Owing to the dorsal margin of the abdomen in the male being shorter than the ventral the abdomen is tail-tilted. In the female, the dorsal edge of the abdomen is quite as long as the ventral edge; also, in place of the coiled chitinous plates found in the male, oval-shaped eggs can be made out.

Pulex irritans is the common flea of man. It has no pro-thoracic comb of bristles, while those on the head are limited to the one found at the posterior and inferior angle of the head, and to one near the lower margin of the eye. Its barrel-shaped eggs are deposited in cracks of floors or wood, and produce legless larvæ having fourteen segments, which larvæ, after about eleven days, are transformed into pupæ; the adult flea emerges some eleven days later.

Pulex felis or common flea of the cat and dog will also bite man. It is distinguished by having both a peri-oral and a pro-thoracic comb of bristles.*

Pulex cheopis is the common flea of rats in India and other warm countries. In general characters it resembles P. irritans, but it is smaller and lighter coloured; also, the number of bristles on the head is greater. The ocular bristle in P. cheopis is situated nearly on a level with the upper border of the eye. The anti-pygidial bristles are longer than those found in P. irritans. In the case of males, the shape and size of the claws serves to distinguish the two species (Plate XIV.). This flea is concerned intimately in the transmission of plague bacilli † not only from rats to rats, but from these and other infected animals to man.

Fig. 132.—Sarcopsylla penetrans.

Sarcopsylla gallinacea is a flea commonly found on birds. It resembles P. irritans and P. cheopis in having neither a peri-oral nor pro-thoracic comb of bristles, but it is readily distinguished from them by its angular-shaped head and its largely developed mandibles.

Ceratophyllus fasciatus is the flea found usually on *Mus decumanus* or common rat of Britain and Northern Europe. It has eighteen teeth on the pro-thoracic comb and no black spines on the head. The common house mouse occasionally harbours this parasite also, though its usual flea is the *Ctenopsylla musculi*, which has no eyes, but has a comb of spines on the head and pro-thorax, and also four genal spines.

Sarcopsylla penetrans.—Under the name of the jigger or chigoe this is a well-known and excessively troublesome insect, found in the West Indies, tropical America, and some parts of Africa, particularly Algeria, the Sudan, and Zanzibar. The chigoe lives on the ground, and is most abundant in dry sandy soils, particularly near the sea-shore. Dirty native

* Taschenberg: *Die Flohe*, Halle, 1880.

† "Report on Plague Investigations in India," *Journal of Hygiene*, 1906, vol. vi. No. 4; *also* 1907, vol. vii. No. 3, which contains much information regarding the morphology of fleas.

cabins are a very favourite haunt for this insect. It attacks all warm-blooded animals, fixing itself indifferently on the first that comes in its way. In size, the chigoe is smaller than the common flea: it is reddish brown in colour and has a large head, with a broad deep abdomen. Both the male and female are, for the most part, free parasites, the male being always so, and the female up to the time of impregnation. They suck the blood by

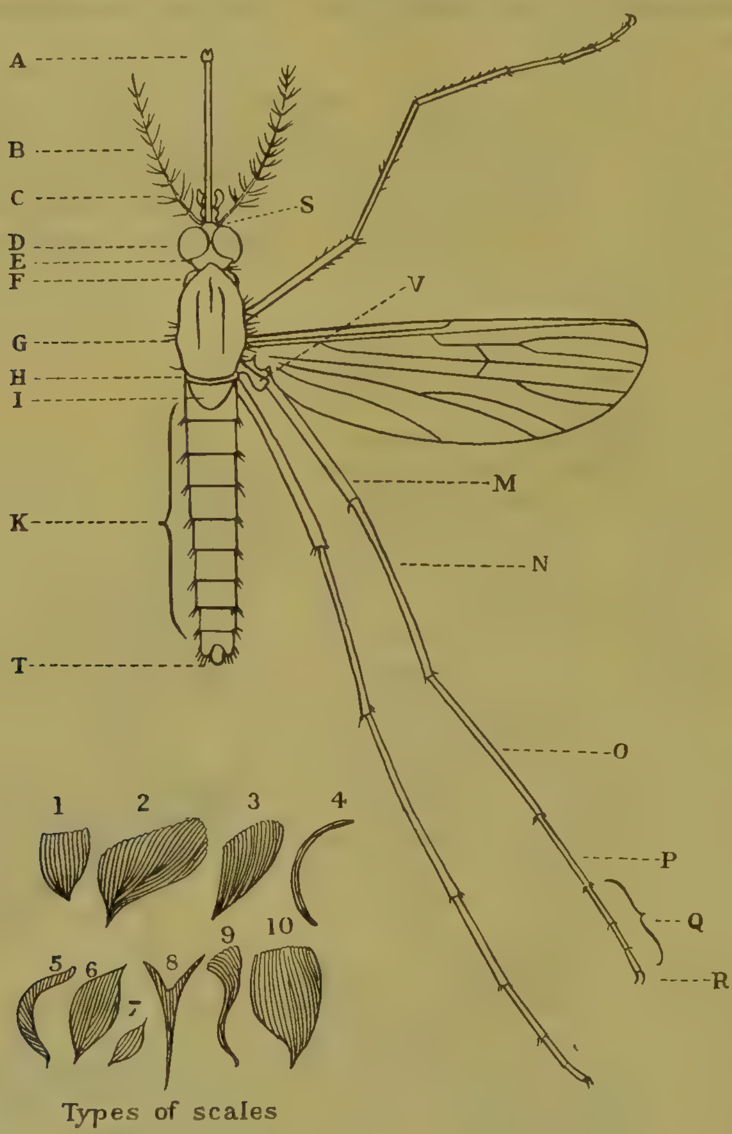


FIG. 133.—STRUCTURE OF A TYPICAL MOSQUITO.

A, Proboscis; B, Antenna; C, Palpus; D, Eye; E, Occiput; F, Pro-thoracic Lobe; G, Mesothorax; H, Scutellum; I, Metathorax; K, Abdomen; M, Femur; N, Tibia; O, Metatarsus; P, First Tarsus; Q, Tarsi; R, Ungues; S, Clypeus; T, Basal Lobe; V, Haltere.

piercing the skin on every available chance, dropping off when gorged. While the male retains the ordinary habits and form of a flea, the female, when she has been impregnated, bores her way into the skin of the foot, leg, thigh, scrotum, or other parts of the body, and becomes, by the enormous development of the ovary, a simple motionless bladder embedded in the flesh, around which, in course of time, when the eggs have to be extruded, a certain amount of inflammation arises. In due time these are hatched, producing a

larva which, after enclosing itself in a cocoon and passing through a nympha stage, emerges in eight or ten days' time as the perfect insect (Fig. 132).

The **Culicidæ** or **Mosquitoes** represent the most important family of dipterous insects, as they are hosts of many parasites. They are characterised by having the anterior pair of wings membranous, whilst the posterior pair are represented by a pair of club-shaped processes known as halteres or balancers. To the head are attached the sensory and biting organs, consisting of two compound eyes, two antennæ, two palpi, and a

Fig. 134.—A, Heads of Male and Female Culicina. B, Heads of Male and Female Anophelina (after Giles).

complex suctorial and piercing organ, the proboscis. To the thorax are articulated a pair of wings, a pair of balancers, and three pairs of legs, whilst the abdomen is segmented and terminates in the anus and external genitals. The general structure of a typical mosquito is shown in Fig. 133. As a rule, the males may be told from the females by their antennæ being plumose, whilst in the females they are pilose (Fig. 134), but this does not invariably hold good. The labial palpi are variable in regard to their form and number of joints; in the Anophelina, they are long in both sexes, as long or nearly so as the proboscis, and more or less clubbed in the males; in the Culicina, they are long in the males, short in the females. The head, thorax, abdomen and legs are covered with scales in most of the genera, whilst on the

wings, scales are only found at the edge and on the veins. The character and arrangement of the scales are important points in the differentiation of genera. The chief varieties of scale are shown in Fig. 133, numbered from 1 to 10. The following are the main types of scale:—(1) flat, spade-shape; (2) mansonia scales; (3) small, broad, asymmetrical scales; (4) hair-like curved scales; (5) narrow, curved scales; (6) spindle-shaped scales; (7) small spindle-shaped scales; (8) upright, forked scales; (9) twisted, upright scales; (10) pyriform scales.

The following classification of the Culicidæ, based on the adult characters only, has been suggested by Theobald; it is a modification of one put forward by Lutz.

CULICIDÆ.

- ANOPHELINÆ. Proboscis straight: palpi long in both sexes.
- ORTHORHYNCÆ. Proboscis straight: palpi short in female, long or short in male.
  - METANOTOPSILÆ. Metathorax nude.
    - HETEROPALPÆ. Palpi long in male, short in female.
      - CULICINÆ. Wings with six long veins.
      - HEPTAPHLEMOMYINÆ. Wings with seven long veins.
    - MICROPALPÆ. Palpi short in both sexes.
      - ÆDINÆ. Abdomen simple.
      - HÆMAGOGINÆ. Abdomen notched below.
  - METANOTOTRICHÆ. Metathorax with scales or chætæ.
    - HETEROPALPÆ. Palpi long in male.
      - HYLOCONOPINÆ.
    - MICROPALPÆ. Palpi short in both sexes.
      - DENDROMYINÆ.
- ANKYLORHYNCÆ. Proboscis curved.
  - TOXORHYNCHINÆ. Palpi short in female.
  - MEGARHININÆ. Palpi long in both sexes.

Of the numerous genera recognised, the only ones known to be of sanitary interest are Anopheles, Myzomyia, Pyretophorus, Myzorhynchus, Nyssorhynchus, and Cellia among the Anophelinæ, together with Culex and Stegomyia among the Culicinæ. It is probable that all the other anopheline genera may be connected with malaria, and the culicine Mansonias and Tæniorhynchus with filariasis. So far no disease has been traced to the Ankylorhynchæ, the micropalpous Metanotopsilæ, nor to any of the Metanotrichæ.*

In common with all other insects showing complete metamorphosis, the mosquito passes through four stages, the egg, the larva, the nymph, and the imago or perfect insect. Almost all mosquitoes are aquatic in their larval and pupal or nymph stages, hence any small collection of water may form breeding-grounds for these insects. The commonest species of mosquitoes having a medical interest belong to one or other of the genera mentioned above. The anophelinæ are of importance and interest, as most members of this family apparently can and do convey the malarial parasite from man to man. The culicinæ are associated chiefly with the transmission of filaria, and one genus, stegomyia, with the dissemination of the micro-organism of yellow fever.

* Theobald: *Monograph of the Culicidæ of the World*, vols. i. and ii. (1901), vol. iii. (1903), vol. iv. (1906); *also* Atlas of fifty-seven plates.

The eggs of mosquitoes are rarely more than one millimetre in size. When first laid they are white in colour but soon become brown or black. They are laid on the surface of water, and if submerged will not hatch out. In the case of *anopheles* and some species of *stegomyia* each egg is separate and kept afloat by means of an air-cell. In *culex* and *tæniorhynchus*, hundreds of eggs are cemented together to form rafts, each egg being perpendicular with its larger end downwards. In culex, the egg-rafts are broad and flat, in tæniorhynchus, the egg-raft is elongated and tilted up at the ends (Fig. 135). In *mansonia*, the eggs are often laid singly and have a curious snout-like projection; in *psorophora*, the eggs are large, laid in patterns like those of anopheles, and covered with minute prickly scales.*

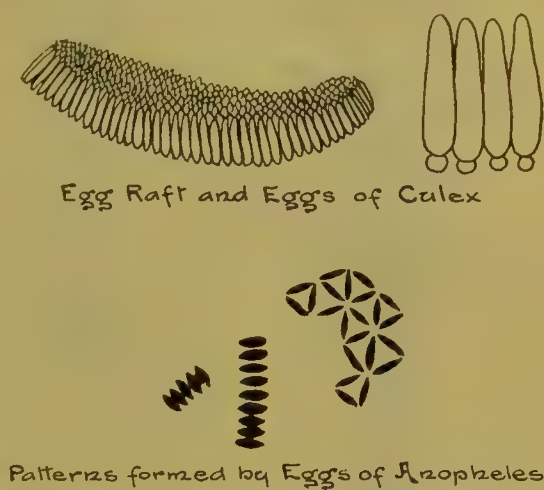


Fig. 135.

After a few days, the eggs hatch out into larvæ. The long legless larva has a flattened head with a fairly broad rectangular thorax, on which there are bristles, and a segmented abdomen with lateral bristles. The stigmata or air apertures are placed dorsally at the posterior half of the abdomen; in anopheles they are close to the surface of the body, in culex, stegomyia and tæniorhynchus they are on the free end of a tube. On the arrangement of the air stigmata, the position of the larva in the water largely depends. The larva of anopheles lies almost horizontally beneath the surface of the water, whereas the larva of culex and stegomyia hangs head downwards, the point of the air-tube only touching the surface. In culex, the air-tube is long, in stegomyia, it is short and thick, in tæniorhynchus, the tube is very long. The larva of stegomyia is much longer than that of culex, also characterised by lashing movements when disturbed. This larva spends much of its time at the bottom of the water, and then lies for the most part horizontally. Its head is small in proportion to the rest of the body, and the thorax is less conspicuously marked off from the abdomen than in culex. Some common larval forms liable to be mistaken for those of mosquitoes are shown in Fig. 139; they are those of Dixa, Corethra, and Chironomas. In about a fortnight, the larva is fully grown and becomes a pupa (Fig. 140). The pupa or nymph shows curious jerky movements,

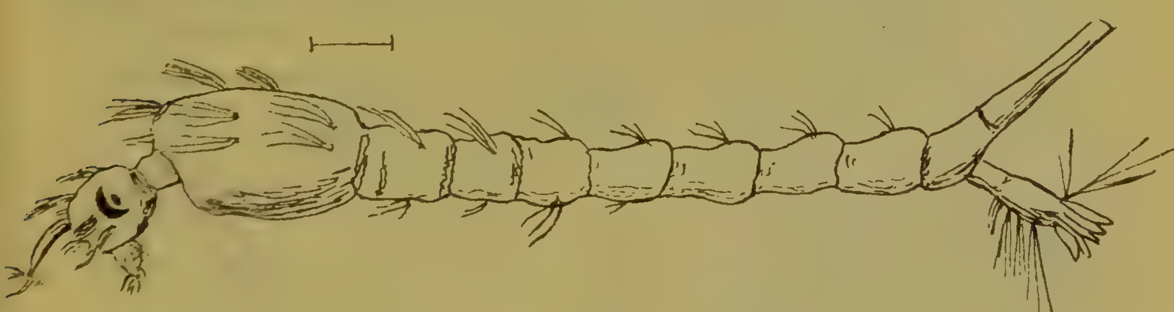


Fig. 136.—Larva of a Culex (after Miall).

* Blanchard: *Les Moustiques*. Paris, 1905.

remains in the water and partakes of no food. In shape the pupa is not unlike a tadpole, but the differences in the nymphæ of various genera are not well marked. Above the thorax are small breathing-tubes for the conveyance of air to the tracheal system. After three or four days, the imago or perfect insect hatches out and flies away. No attempt can be made, in this work, to describe the various genera among the mosquitoes, but the following summarised notes on the chief sub-families which have a parasitic interest for man may be useful to some.

FIG. 137.—LARVA OF AN ANOPHELINE (AFTER E. E. GREEN).

Anophelina.—This family contains many genera, found either in temperate climates or in the cooler regions of warm climates. The type is the European and North American *A. maculipennis.* This species and *A. bifurcatus* are true malaria carriers, but it is probable that the whole family can be equally incriminated.* Anophelines may be told from other culicidæ by the combined characters of the long palpi in both sexes, the total absence of flat thoracic and scutellar scales, and their straight proboscis. Many species have spotted wings, and when stationary are at an angle to the resting surface, the head, thorax and abdomen being in one line; there are, however, some exceptions to this rule. The larvæ of all anophelines have no respiratory siphon, and when at the surface of the water lie nearly parallel with it. Many of these mosquitoes are sylvan, while a few, like A. maculipennis, are domesticated. About one hundred and fifteen species are known.

Culicina.—This is a large sub-family whose members have a straight proboscis; short palpi in the females, long in the males; the metanotum is nude, and they have only six scaled longitudinal veins on the wings. Some thirty-five distinct genera are known, which can be distinguished by the squamose ornamentation of the head, thorax, legs and wings. The types are *C. pipiens* or the common gnat of Europe, and *C. fatigans* or the common gnat of the tropics. This latter is one of the species that has been proved to transmit filariæ to man. Owing to the different length of the legs, the body of culex approaches the resting-place closely, the abdomen being more or less parallel to the resting-surface. The posterior pair of legs is directed towards the dorsum. The genus *stegomyia* belongs to this subfamily and is of importance owing to its connection with yellow fever. It

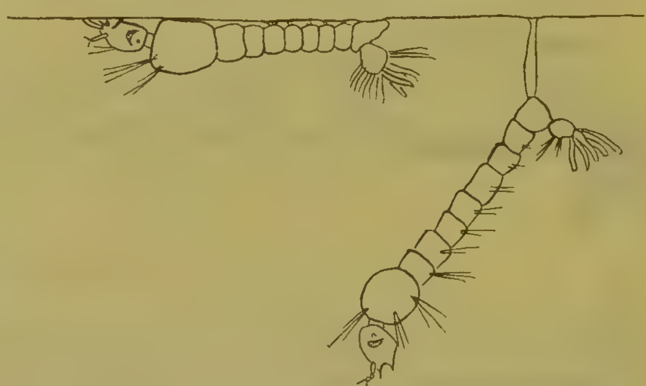
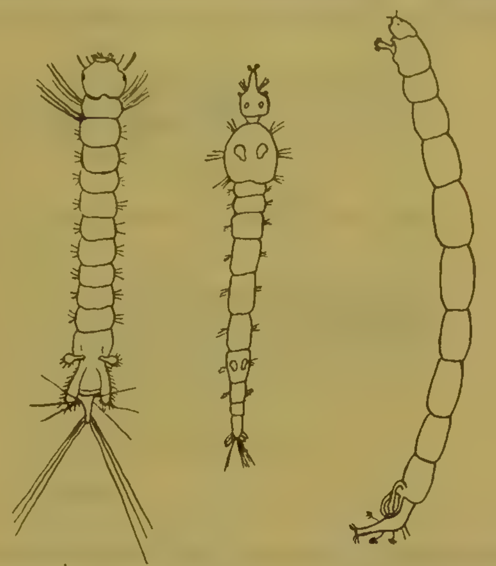


FIG. 138.—SHOWING USUAL ATTITUDE ASSUMED BY ANOPHELINE AND CULICINE LARVÆ IN WATER.

* Nuttall: "Studies in Relation to Malaria," *Journal of Hygiene*, 1901, vol. i. p. 451.

is easily told by the head and scutellum being clothed entirely with flat scales. The stegomyiæ are mostly black and white mosquitoes, the best-known species being *S. fasciata*; it is found in all parts of the world between 40° N. and S. It is a vicious biter both by day and night, and breeds in all small artificial collections of water. The characteristic feature of this species is the ornamentation on the thorax, which has a curved silvery line on each side and two dull yellow parallel ones in the middle; there are some minor variations to this adornment, chiefly the absence of median thoracic stripes.

Among the flies which may be mistaken for mosquitoes are the *simulidæ* or sand-flies, the *chironomidæ* or midges, and the *psychodidæ* or owl midges.



Larvae that may be mistaken for Mosquito Larvae.

FIG. 139.

The sand-flies are all small, stoutly built, dark-coloured flies with large wings. The larvæ are aquatic and hold on to stones, grass, weeds and roots. When young they are transparent, usually getting grey or brown later. They prefer running water to still. The pupal stage is passed in a small shoe-shaped cocoon, open at one end. The adult flies are restless and gregarious.

The midges not only can be mistaken for mosquitoes but are equally annoying to man. They are distinguished easily from the culicidæ by the following characters:—(1) small head, often drawn under a cowl-like thorax; (2) no scales to the body or wings; and (3) the different arrangement of veins on the wings (Fig. 141).

Nymphae of Anopheles and Culex.

FIG. 140.

The owl midges are noticeable for their very hairy wings and bodies, and general moth-like appearance. The proboscis is short. The larvæ are aquatic and feed on rotting vegetable matter; they are more or less cylindrical, with short air-tube. The pupæ have two long tube-like anterior stigmata. The various brachycerous flies, or those with short antennæ, present no species which have a pathological interest for man, though several varieties are suspected of conveying blood parasites among animals and possibly may be concerned in a similar act towards man. The more important members of this group are the tabanidæ or gadflies.

Tabanidæ.—This is a family of blood-suckers of world-wide distribution and includes a number of species known variously as horse-flies, gadflies, breeze-flies, mangrove-flies, and seerut-flies. In general appearance the

tabanidæ are large flies varying from 6 to 25 millimetres in length; in them the head is large, and in the male composed almost wholly of eyes, which meet together above in that sex, but are separate in the female. The proboscis is commonly short and stout, while the antennæ are always prominent. The principal genera are pangonia, chrysops, hæmatopota,

Fig. 141.

and tabanus. The two first named are characterised by having the hind tibiæ with spurs at the tip, while the two last mentioned have no spurs on the hind tibiæ. In *pangonia*, the proboscis is often long and the third joint of the antennæ is eight-ringed. In *chrysops*, the antennæ is usually long and slender, the third joint being composed of five rings; the eyes are brilliant and of a greenish purple hue. In *hæmatopota*, the thorax and abdomen are without an iridescent tomentum, and the head of the female is often as broad as long. In *tabanus*, the eyes are bare, also the last joint of the antennæ is annulated and notched in crescentic form; the members of this genus are nearly all large flies.

Fig. 142.—Hæmatopota. Sp. (?). ×4. Showing Resting Position of the Wings. Reproduced by permission of the Trustees of the British Museum.

The general colour of the tabanidæ is sombre, the prevailing hue being brown, but the pattern of the markings varies with the species. The eggs of these flies are deposited in masses on rushes over water or on wet ground. The larvæ hatch out as whitish cylindrical carnivorous grubs, tapering at each end and living in wet mud or sand near the margins of rivers or other sheets of water. The pupæ or nymphs have a pair of large ear-shaped spiracles on the back of the thorax, and are concealed commonly in damp rubbish at the edge of water. Of the adult flies, the females are persistent blood-suckers, preferring horses and cattle, although certain species appear to attack man. Some of the smaller flies belonging to the genera hæmatopota and chrysops are curiously silent in their flight; on the other hand, the larger species of tabanus and of pangonia betray their approach by a loud hum. In some species of tabanus, the wings are banded conspicuously with blackish brown, while in hæmatopota they show an intricate pattern of

PLATE XV.

Chrysops distinctipennis (Austen). ♀ × 6
Hæmatopota pulchrithorax (Austen). ♀ × 5

Reproduced by permission of the Department of Education, Sudan Government, Khartoum.

light markings on a dark ground. In the resting state, nearly all species show the wings to diverge at the tips, but meet at the base (Fig. 142).

Our knowledge of the tabanidæ has been much extended during recent years, especially in many parts of Central Africa, mainly by the work of Balfour, Gray, Dansey-Browning, Dunn, Flower, and others.* The more important members of this family are the following :—

Hæmatopota pluvialis is a familiar species in this country during the summer. It has been known to bite man severely.

Hæmatopota pulchrithorax has a geographical distribution extending from Zululand to the Sudan ; it belongs to a group the members of which resemble each other closely in the markings on the dorsum of the thorax and of the wings (Plate XV.). The grey median thoracic stripe clearly

FIG. 143.—TABANUS BOVINUS. × 3.

shown by this species is much reduced occasionally in other members of the group, but in all, its characteristic outline is distinctly traceable. There is a narrow median grey stripe on the abdomen. The general colour of this fly is reddish brown. The light markings on the wings are whitish in the males and yellowish in the females. The tibiæ have two yellowish bands. Average length of these flies is 11 mm. ; the width of head is 4 millimetres.

Chrysops distinctipennis is another fly common in Uganda and adjacent districts. The head and thorax are black, with a dull olive-grey abdomen. Each segment has a black median blotch on the dorsum, not reaching to the hind margin of each segment, except the last. The legs are ochraceous, with brown tarsi, also black coxæ and trochanters. The wings are marked by a brown transverse band ; the halteres are dark brown. The average length of these flies is 9 millimetres (Plate XV.).

Tabanus bovinus or the common gadfly of oxen is a familiar specimen of the genus in this country. It is a free blood-sucker, but at

* Second Report of the Wellcome Research Laboratories at Khartoum, 1906. This Report contains a valuable account of the biting flies of the Sudan by E. E. Austen, and should be consulted for details.

present not known to be associated with the dissemination of any specific disease (Fig. 143).

Tabanus ditæniatus is a greyish yellow fly some 12 millimetres long, common in Central Africa from Natal to the Bahr-el-Ghazal, and having a pair of conspicuous black dots on the front of the head. The abdomen

FIG. 144.—TABANUS DITÆNIATUS. ♀ × 3.
Reproduced by permission of the Department of Education, Sudan Government, Khartoum.

is ochre-buff in colour, with three longitudinal black or brown stripes, on the centre one of which is a yellowish pollinose line; the antennæ and legs are

FIG. 145.—TABANUS GRATUS. ♀ × 3.
Reproduced by permission of the Department of Education, Sudan Government, Khartoum.

yellow (Fig 144). The wings are hyaline, with pale yellow veins. The halteres are yellowish.

Tabanus gratus is a greyish buff fly some 11 millimetres long, found in Africa from Zululand to Nigeria. It has two conspicuous callosities on front, and the third joint of the antennæ is rufous. The dorsum of the thorax is ashy grey with pearl-grey longitudinal stripes; the scutellum is

greyish chestnut; the abdomen dark brown above, with three grey or yellowish longitudinal stripes converging towards the tip. The legs are ochre and the wings hyaline (Fig. 145).

Tabanus biguttatus is a large black fly about 21 millimetres long, common in the Sudan and Abyssinia. It has dark brown wings with white tips. The male has two conspicuous cream-coloured spots on the dorsum of the abdomen in the median line. These spots are absent in the female, but she has an inverted heart-shaped patch of black hair in middle of the dorsum of thorax. In both sexes the legs are black and the wings dark brown, except at apices.

Tabanus fasciatus is found in many parts of Uganda and the Congo region. It is 16 millimetres long with an ochre-buff-coloured head and thorax; the abdomen is tawny yellow with a distinct suggestion of green; the wings are brown with a transverse band across the middle. This fly is closely related to *T. niloticus* found on the White Nile; in this latter species the front tibiæ appear to be slightly more slender than in the typical form (Fig. 146).

Fig. 146.—Tabanus fasciatus. ♀ × 2.

Tabanus africanus is a handsome fly common in the Bahr-el-Ghazal. It is tawny ochre in colour with black legs, the tibiæ of which are swollen. Wing markings are brown, with a patch of white hair at the base of each. This fly is similar to *T. latipes* of Senegal; both belong to the "fasciatus" group, which have ferruginous coloured bodies, swollen front tibiæ and banded wings.

The third group, cyclorrhapha, of the diptera includes the muscinæ, the sarcophagidæ, and the œstridæ. Only some of the first group are blood-suckers, while those of the last two are not so at all.

The *muscinæ* is a large group, the most familiar species being *Musca domestica* or common house-fly. This insect is widely distributed and undoubtedly associated with the dissemination of enteric and other bacilli. Two members of the genus pycnosoma, namely, *Pycnosoma marginale* and *P. chloropyga* (Plate XVI.), swarm about filth trenches and breed in fæcal matter and offal of all kinds in India and the tropics. P. marginale is a thick-set fly measuring 12 millimetres, with an orange-buff-coloured face, and shining metallic plum-purple or metallic-green body, recognisable at once by the dark brown front border to the wings, which have an average expanse of 22 millimetres. P. chloropyga is a much smaller fly, measuring only some 10 millimetres in length. The whole body is metallic bluish green, or metallic plum-purple, the last two segments of the abdomen being brassy green. The wings are hyaline, with a dark blotch near the base; the average wing expanse is 18 millimetres.

Homalomyia canicularis (Fig. 147) is another fly which is very common in dwellings and presents a certain resemblance to the true house-fly, owing to the fact that the male also possesses ochre-buff-coloured lateral patches at the base of the abdomen. H. canicularis is, however, much smaller and narrower; it is further distinguishable by the fourth vein running straight to the tip of the wing, instead of being bent up at

an angle as in Musca domestica. Both H. canicularis and the closely allied H. scalaris are of importance, since it is the larvæ of these species

Fig. 147.—Homalomyia canicularis. × 6.

which are responsible for many cases of internal myiasis, the larvæ being ovi-deposited on the anus when the person has been using some open latrine or privy where these flies are common.* The larvæ of these flies and also of Lucilia macellaria (Fig. 148) may be found in the nose and other cavities, or even open sores on man's body.

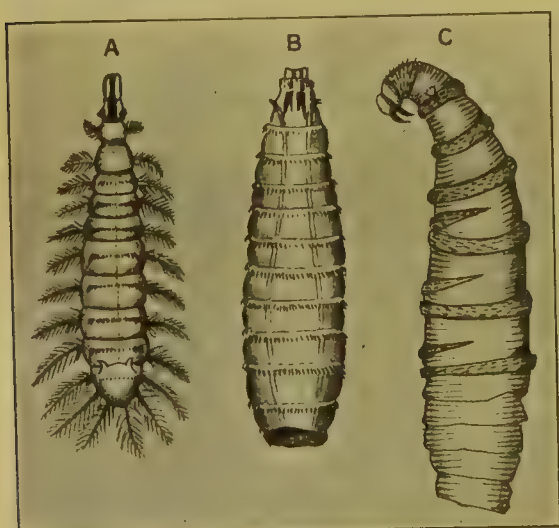


Fig. 148.

A, Larva of Homalomyia canicularis. × 6.
B, Larva of Musca domestica. × 6.
C, Larva of Lucilia macellaria. × 4.

The chief interest of the muscinæ centres in the sub-section stomoxys and the genus glossina.

Stomoxys calcitrans (Fig. 149) is widely distributed throughout Europe, India and the United States. Though somewhat more stoutly built, in size and coloration, it resembles closely the common house-fly; the little black piercing proboscis projecting horizontally in front of the head, however, affords a reliable means of recognition. The grey or olive-brown body generally shows a light median stripe on the thorax, and dark

* Austen: "The House-fly and Allied Species as Disseminators of Enteric Fever," *Journ. Roy. Army Med. Corps*, 1904, vol. ii. p. 651.

PLATE XVI

PYCNOSOMA MARGINALE. ♀ × 4.

PYCNOSOMA CHLOROPYGA. ♀ × 4.

spots or transverse bands on the abdomen.* The larva is a white maggot, closely resembling that of the house-fly, and is found in horse or other manure. This fly is a free sucker of blood, and a source of great irritation to many animals. It is not unlikely that a species of stomoxys may be associated with the dissemination of the trypanosome of surra among horses and other animals; while, according to Noë, S. calcitrans is the undoubted means of transmitting filaria among oxen.

FIG. 149.—STOMOXYS CALCITRANS. ♀ × 5.

The genus *glossina* is chiefly of interest as it embraces the notorious tsetse flies, associated not only with the spread of the South African cattle disease ngana, but also with the more widely prevalent human disease known as sleeping-sickness. Glossina are dull-coloured brown flies, 7 to 10 millimetres long, excluding the proboscis and wings. The abdomen is generally, but not always, marked by pale brown bands interrupted in the middle. When resting, the wings are closed flat one over the other, like scissors (Fig. 150), projecting beyond the abdomen. In this attitude, tsetse-flies can be distinguished from all other blood-sucking diptera, especially those belonging to the genera hæmatopota and stomoxys, which are those most likely to be mistaken for them. The proboscis is enclosed in the palpi and projects horizontally in front; its base is expanded into a bulb. The arista is feathered on the upper side only. The sexes of these flies can be distinguished readily, since in the male the external genitalia form a knob-like protuberance—the hypopygium—beneath the end of the abdomen. This is absent in the female. Tsetse-flies do not appear to lay eggs, but extrude a yellow-coloured larva. On being born, the larva creeps about and burrows finally into a hole, where it soon changes colour and in a few hours becomes a hard black pupa or nympha.†

FIG. 150.—GLOSSINA LONGIPENNIS. × 4. IN RESTING ATTITUDE, SHOWING POSITION OF THE WINGS. Reproduced by permission of Trustees of the British Museum.

A considerable number of species of glossina are now known, such as Gl. palpalis and Gl. pallicera, in which the hind tarsi are entirely black; Gl. morsitans, Gl. longipalpis,

* Tulloch: "The Internal Anatomy of Stomoxys." *Journ. Roy. Army Med. Corps*, 1906, vol. vii. p. 154.

† Austen: *A Monograph of the Tsetse-flies*. London. 1903. Published by Trustees of the British Museum.

Gl. pallipedes, Gl. longipennis and Gl. fusca, in which the hind tarsi are not entirely black. The trypanosome of ngana cattle disease is disseminated by Gl. morsitans, while that of sleeping-sickness is spread certainly by Gl. palpalis, and possibly by some other species.

Glossina palpalis in general colour is dark brown; the thorax is usually paler, with dark brown markings on a greyish ground. The abdomen presents generally an indication of a pale longitudinal median stripe, with pale lateral triangular markings, and usually the hind margins of the segments narrowly pale. The legs, except the hind tarsi and last two joints of the front and middle pairs, are buff-coloured; usually the femora are a dark brown and the tibiæ yellowish. The face is yellow, covered with greyish dust, while the posterior surface of the head is entirely cinereous; the frontal stripe varies from an ochre to chestnut in colour. The second joint of antennæ is yellow in front, arista yellowish but dark brown on the under side. Palpi are cinereous. The bulb at base of proboscis is dark brown. The wings are uniformly brownish, the squamæ are white with the antisquama darker, and fringed with short dark hairs. The halteres are yellowish white (Plate XVII.).

Glossina morsitans is mouse-grey in general colour, the thorax

FIG. 151. — GLOSSINA MORSITANS. NATURAL SIZE. From *Journal of the Royal Army Medical Corps.*

FIG. 152.—PUPA OF GLOSSINA MORSITANS. × 8. Reproduced by permission of Trustees of the British Museum.

being somewhat paler in front, with more or less distinct brownish longitudinal markings. The abdomen varies from a drab-grey to ochraceous buff, the segments from the third to the sixth inclusive having conspicuous dark brown bands interrupted in the median line, not reaching the lateral margins and not extending beyond the basal three-fourths of each segment. The tips of the last two joints of the front and middle tarsi are dark brown, contrasting sharply with the rest of the leg. The head and face are a pale yellow covered with cinereous dust, the frontal stripe varying from a buff to ochraceous colour. The antennæ are greyish buff, the third joint being markedly infuscated. The palpi are buff, more or less cinereous above and with infuscated tips. The wings are faintly brown, the halteres are yellow (Plate XVII.).

In Fig. 151 is shown a natural-size representation of these tsetse-flies, while in Fig. 152 is given a drawing of the pupa or nympha. This consists of twelve segments like the larval form. The first eleven segments are smooth, but when examined under a low power the surface is seen to be tessellated. The posterior end is characterised by a pit, with tumid lips joined by dorsal and ventral ridges. In the centre of the first segment, which is much smaller than any of the others, at the anterior pole a slight depression exists, representing the mouth of the larva. At the anterior pole, there is a fine seam which opens to permit the escape of the adult fly;

PLATE XVII.

Glossina palpalis. ♂ × 6
Glossina morsitans. ♀ × 6

Reproduced by permission of the Trustees of the British Museum

it is not visible in the drawing, but runs across the first three segments in a lateral longitudinal direction, and ends on each side in a bifurcation on the fourth segment. In shape, the pupa is an elliptical oval body, nearly black in colour and with an obtuse anterior end. If the pupal case can remain in a dry place, the perfect insect hatches out in about six weeks.

The *Sarcophagidæ* are not blood-sucking flies, but their larvæ give rise in some tropical countries to very severe forms of myiasis in both man and animals. The more notorious members of this family are the following :—

Sarcophaga carnaria and **S. magnifica** are common in many parts of Europe, especially Russia, where the ravages of their larvæ are particularly repulsive. The larvæ live in ulcers and in the cavities and canals of man that are directly accessible from the exterior. These flies vary from 10 to 20 millimetres in length and are of a general ash-grey colour ; the thorax is marked with three dark stripes. The abdomen is lighter grey, with three black spots on each segment ; the legs are black and the wings yellow.

Ochromyia anthropophaga is a native of Senegambia where its larva is known as the cayor-worm (Fig. 153). The fly is believed to lay her eggs in the sand, whence the larvæ emerge, and, an opportunity occurring, penetrate the skin of man and animals. Underneath the skin the larvæ grow, giving rise to inflamed swellings ; in seven days they leave their temporary host and pass into the pupa stage. Once the larvæ have emerged, the sores so produced heal quickly.

Fig. 153.—Larva of Ochromyia anthropophaga. × 3.

Bengalia depressa is a large fly half an inch long, with a wing expanse of over one inch. It occurs from Natal to the Sudan, giving rise to serious cutaneous myiasis. The head is large, with two prominent dark brown eyes. The thorax is of a rust colour with dark lateral and dorsal chætæ. The abdomen is pale brown with two dusky bands. The transparent wings are tinged at the bases with dusky brown. The larvæ are half an inch long, dirty white in colour, with deep brown spines. The pupa is stout and oval, of a dark purple and covered with a mealy down. The eggs are white and $\frac{3}{50}$ths of an inch long ; they are laid usually in the hair or on woolly clothing. Occasionally these flies appear to be viviparous. The ovipositor is pointed and eggs may be deposited under the skin. Both this fly and the closely allied species, *Auchmeromyia luteola*, are the maggot-flies of Natal, Rhodesia, and the Congo region * (Fig. 154).

The *œstridæ* furnish the numerous " bot " flies, whose larvæ cause much trouble to sheep, horses, camels, and deer in various parts of the world. The only one reported as causing myiasis in man is the following :—

Cuterebra noxialis.—The perfect insect is about 17 millimetres long, has a yellow head and face, marked by two fine lateral brown stripes which converge anteriorly. The eyes are prominent, but set wide apart. The thorax is a light brown with four grey patches arranged in pairs on the dorsum ; between the anterior pair are two fine longitudinal grey stripes. The abdomen is a deep blue, divided into four segments ; the posterior edge of the three anterior segments being much lighter in colour. This fly is very common in Central America, where it frequents the outskirts of woods, depositing its eggs on man, cattle, and dogs. The larva is the so-called

* Dutton, Todd and Christy : " The Congo Floor Maggot," Mem. XIII. Liverpool School of Tropical Medicine, p. 40.

Macaco-worm of Venezuela and Guiana. The larvæ, when hatched, penetrate the skin and give rise to much irritation; they attain a length of about

Fig. 154.—Bengalia depressa. × 3.
Reproduced by permission of the Department of Education, Sudan Government, Khartoum.

a quarter of an inch, and possess two strong buccal hooklets and a series of spines on the front half of the body.

The *hippoboscidæ* or spider-flies are a widely distributed family of small

Fig. 155.—Hippobosca camelina. × 4.
Reproduced by permission of the Department of Education, Sudan Government, Khartoum

insects which affect chiefly horses and cattle. The more important members are the following:—

PLATE XVIII.

1

2

3

Fig. 1—Hippobosca equina. × 4

Fig. 2—Hippobosca rufipes. × 2

Fig. 3—Melophagus ovinus. × 12

Hippobosca camelina.—This fly is very troublesome to camels in Egypt, the Sudan, and some parts of India. In appearance, this insect is flat, leathery looking and louse-like. The body and legs are of a reddish colour approaching to a dark brown ; the dorsum of the thorax has light yellow markings (Fig. 155). The antennæ are short and embedded in pits. The eyes are round or oval, no ocelli. The abdomen is red-brown, sack-like, and with little or no segmentation. The legs are short, stout, and spiny. The wings are hyaline, ample, and heavily veined at the base and along the anterior border. These parasitic diptera produce young in the puparium stage, the puparia being deposited often only a short time before the flies are ready to escape. The adults fly with short quick movements and hold pertinaciously to the hair of their hosts. These insects produce great irritation, and are of importance, not only as parasites, but as possible conveyers of trypanosomes among camels and other animals.

Hippobosca equina has a very wide distribution, being found most frequently on horses, asses, and mules in Europe, Asia, and Africa. It is the familiar New Forest fly of this country. **Hippobosca rufipes** is another species belonging to this family. This fly is the means of distributing the trypanosoma theileri among cattle in various parts of Africa. A closely allied genus is the **Melophagus ovinus** or ordinary tick-fly of the sheep. Representations of these three flies are given in Plate XVIII.

CHAPTER XVI

THE INFECTIVE DISEASES

In the last chapter, a brief review was given of the most important facts and features in connection with the various fungi, protozoa, and other organisms, belonging to the animal kingdom, which, by virtue of a more or less marked parasitism, produce some well-defined disorders in man and animals. There remains, however, for consideration that large class of micro-organisms—the Schizomycetes or Bacteria—which, in the light of our present knowledge, are now regarded as the active causes of the infective diseases. That most of the infective diseases, hitherto analysed, owe their origin to one or another species of these microphytes is sufficiently well recognised as to need no special demonstration in this place. Further, the general characters of bacteria, their general morphology, size, shape, motility, powers, and mode of multiplication, are so well known, and constitute so large a portion of present pathological teaching, that detailed descriptions under these respective headings would be superfluous in a work of this kind upon Public Health.

Recognising that the Prevention of the Infective Diseases can only rightly result by a proper comprehension of their etiology and natural history, it is intended, in this chapter, only to enumerate very briefly, and without unnecessary discussion, the chief facts in regard to these aspects of some of the more important of the infective diseases. It is true, the term "infective" is open to criticism, especially as applied to some individual diseases hereafter to be considered, but, as expressing the etiological sequence of events of the whole class, it presents advantages which are not to be ignored.

Origin of the Infective Diseases.—It may be assumed that the occurrence of an attack of one of the infective diseases implies the action of microbial life, or the products of microbic life, upon the affected person; further, that the microbe did not arise into being independently, but was the progeny of a similarly endowed parental microbe. These assumptions, while removing all misconception as to the idea of a possible spontaneous generation of disease germs, involve the acceptation of the belief that there is an unbroken continuity of disease descent from antecedent cases. This conception of the origin of the causes of disease, if interpreted literally, implies the belief that every single case of each infective disease is the offspring or result of an antecedent case of the same disease. A little reflection and experience soon indicate that this doctrine is too inelastic for general acceptation, because certain of these diseases affect the lower animals as well as man, and consequently the antecedent case of a given instance of such disease need not be a human case; while, as regards others, the pre-existing case must be sought in man alone.

A fuller knowledge of the life-history of some of the micro-organisms of disease has shown that some are capable of existing outside the body for considerable periods of time, thriving and multiplying either upon human

or animal tissues; others, though capable of existing outside the body for long periods, are apparently incapable of passing through their life-cycle except in living human tissues—so that diseases due to them must arise by direct or indirect infection from a previous human case of the same disease.

It is a matter of common knowledge that variations of severity and type are observed between different epidemics, and between different periods of one and the same epidemic of a given disease. In the same way, individual cases in an epidemic vary both in type and severity. Allowing for possible differences in the persons attacked, and for possible differences of dose of the virus, there is always the possibility of differences due to variations of pathogenic power on the part of the species of micro-organism. This latter may result from a variety of causes, such as warmth, light, moisture, and the suitability or otherwise of the soil which they may happen to invade.

Infection, Contagion, and Inoculation.—According to the manner in which these diseases are transmissible from one person to another, so are they spoken of as being either infectious, contagious, or inoculable. As a certain laxity prevails in the use of these terms, their proper definition is of importance. By *Infection* is meant the conveyance of the poison in some indirect way, through the medium of the air, water, soil, food, clothing, &c., and its entrance within the recipient's body through the skin, or mucous membranes, but without any breach of continuity of surface. *Contagion* means transference of the poison by actual contact, but without breach of surface in the recipient. *Inoculation,* on the other hand, implies the conveyance of the poison, either directly by actual contact with the diseased body, or indirectly by means of some instrument or other article from the affected to the unaffected person, an essential feature of the procedure being some breach of surface in the skin or mucous membrane. While some diseases are only capable of being transmitted by inoculation, others are both infectious and inoculable.

The mere introduction of pathogenic germs into the animal body is not in itself sufficient to cause disease under all conditions. What will happen depends on many factors, some connected with the infecting germ, some with the infected organism. From the side of the bacteria or germs, the following are important:—dosage or number of bacteria introduced, virulence, path of infection, and the interaction of various organisms or concurrent infection by several germs. Of the conditions in the infected animal or person modifying pathogenic action, the most important is susceptibility or predisposition; this may be either natural or acquired. The cause of individual predisposition we do not understand, and sometimes it is entirely or partially absent. In any case predisposition to infection depends, probably, on a variety of factors; among the most important of these are intrinsic cell properties and extrinsic conditions reacting harmfully on the body and its tissue processes. Within certain limits an organism has special cellular mechanisms which may ward off infections, but these can be profoundly modified and weakened as by such circumstances as starvation, fatigue, loss of blood, unsuitable diet, exposure to heat, cold, and moisture. This being so, we can understand the nature of endemicity or the state of the individuals living in a certain area being such as to favour a certain infective disease. In contra-distinction to predisposition, which applies to certain individuals of a species, there is a racial predisposition to infection which applies to all members of a species; examples of this nature are well known. Finally, age is a disposing factor for some infections and the converse in others.

Like other characteristics, a tendency to disease can be transmitted

from parent to offspring; this is so-called hereditary predisposition, and may be either specific or non-specific. We have not space here to discuss the relative merits of the part played by inherited tendency as compared with the part played by actual transmission of the infective agent from parent to child, but a careful study of the many experiments and observations which have been made on this difficult problem suggests the need of caution in the use of the term heredity in respect of infective diseases.

Incubation.—Assuming that infective material is living in the form of a primitive plant-cell capable of growing and multiplying within the bodies of men and animals, the course of an infective disease is truly the life-history, so to speak, of a lower plant, and, as such, has a period of development, a period of its greatest vigour, and a period of decline or death. The time of development, or, as it is usually called, the period of *incubation*, is a most important feature in all the infective diseases, and may be defined as that period which elapses between actual infection and the appearance of the first signs or symptoms of the disease. This period varies considerably as regards different infections, ranging from a few hours in the case of some of them to weeks in the case of others, and even years possibly in one or two others. The following table, therefore, may be regarded only as an approximate statement:—

Disease.	Period of Incubation.	Duration of Infectivity.
Chicken-pox	10 to 14 days.	3 weeks.
Cholera	1 to 5 ,,	3 ,,
Diphtheria	1 to 8 ,,	6 ,,
Diarrhœa	1 to 4 ,,	1 to 2 ,,
Enteric fever	8 to 14 ,,	6 ,,
Erysipelas	1 to 5 ,,	1 ,,
Influenza	1 to 4 ,,	3 ,,
Measles	8 to 20 ,,	4 ,,
German measles	6 to 14 ,,	3 ,,
Mumps	14 to 22 ,,	3 ,,
Scarlet fever	1 to 6 ,,	6 to 8 ,,
Small-pox	12 ,,	6 ,,
Tuberculosis	unknown	During the whole disease.
Typhus fever	6 to 14 days.	4 weeks.
Whooping-cough	4 to 14 ,,	8 ,,

For each different infection, however, the period is comparatively constant; though variation, within certain limits, occurs in different individual cases of the same disease, the period being more constant in some than in others. The incubation period is an important fact to know in connection with all infectious diseases, inasmuch as it enables us to say, when a person has been exposed to infection, that after the lapse of a certain number of days, if not already attacked, that person is safe and may mix with other people without risk to them. At present we know very little about the changes which take place in the body during incubation, beyond that the poison is multiplying in some part of the system. The majority of these diseases have a short and limited course, ending either in death or recovery more or less complete. A few, like chicken-pox, mumps, and German measles, are remarkably mild in their symptoms; but, on the other hand, a few are liable to vary greatly in their intensity. This is particularly so with both scarlet fever and small-pox. A general rule seems to be that severity or mildness holds good for the majority of cases occurring in a given outbreak, but that the severer cases are more common in the earlier than in the latter

part of an outbreak. Age, sex, race, and season also have an important influence upon the severity of infectious disease attacks.

These, and many other points connected with infectious diseases, are still imperfectly understood.

Manner and Periodicity of Prevalence of Infective Diseases.—It is not unusual to speak of the general manifestations of the infective diseases as being either epidemic or endemic. The term *epidemic* merely signifies a tendency on the part of the disease to spread over a large area of the earth's surface, or in a given community, regardless of local circumstances. The term *endemic* indicates that a disease tends to remain among the inhabitants of a particular locality, and is apparently largely influenced by local conditions. Going back to the first causes of these diseases, it would seem probable that epidemic diseases are due to micro-organisms which thrive best in living animal tissues, whereas endemic diseases are mainly due to microbes whose habitat is outside human and animal bodies, and therefore largely influenced by local circumstances.

The classical reviews of Whitelegge * and Hamer † indicate that the more common and fatal infective diseases " observe definite periodic times or cycles," which may be described as " a succession of waves, the periods covered by the waves differing for different diseases." These waves are of two essentially different kinds—the accidental and the fundamental. The former is a wave of mere prevalence, and, as Whitelegge puts it, " probably but a reflex of changes in the environment." The true or fundamental cycle or wave is characterised by an increase of both prevalence and severity, and often extends over a considerable number of years. Though possibly not altogether independent of changes in environment, the true wave of periodicity of the infective diseases is more probably associated with microphytic evolutionary processes.

Immunity and Protection.—We have referred to the differences in susceptibility to infective disease exhibited by different individuals and different races or species, and, by implication, recognised the existence of a converse state of insusceptibility. When an animal species is infected with an organism or germ, but does not develop disease, that species is said to show immunity against the organism. This immunity varies in degree in both individuals and species, and may be naturally possessed by a human being or animal, or it may result from the individual passing through an attack of the disease. For these reasons, it is customary to speak of immunity, as it is found in ordinary conditions, as being either natural or acquired ; further, acquired immunity may be either active or passive.

Active immunity is produced by injecting organisms either in an attenuated condition or in non-fatal doses, or by injecting non-fatal doses of the products of the organisms. Passive immunity, on the other hand, depends on the fact that if an animal be immunised by either of the above processes, its serum, when injected into another animal, together with the organism, may either possess the power of neutralising the toxins of the organism, *i.e.*, may be anti-toxic, or it may have no effect on the toxins, but may prevent the action of the living organism, *i.e.*, it may be anti-bacterial. Active immunity is usually of long duration and not transmissible to the fœtus ; passive immunity, on the other hand, is soon lost, but, while present, is transmissible to the fœtus. When active immunity is produced by the

* Whitelegge : " Changes of Type in Epidemic Disease," Milroy Lecture, *Brit. Med. Journal*, vol. i. 1893.

† Hamer : " Epidemic Disease in England : the Evidence of the Variability and Persistency of Type," Milroy Lecture, 1906.

injection of living organisms, the cultures are usually attenuated either by growing them in the presence of a current of air or oxygen, by passage through the tissues of another animal, by the influence of abnormal temperatures, or by growing them in the presence of weak anti-septics. These attenuated cultures are often called vaccines. Instead of attenuating the cultures by the above means, non-fatal doses of virulent cultures may be injected in gradually increasing amounts. Active immunity may also be produced by the injection of dead cultures. In some cases only the intra-cellular toxins, or those produced in the bodies of the organisms, are introduced, as when the vaccine is obtained from the surface of a solid medium; in other cases the extra-cellular toxins only are injected, as when the bacteria-free filtrate from a broth culture is employed.

Passive immunity.—It has been found that the serum of an animal treated by gradually increasing doses of the toxin of a particular organism, will protect a second animal against a certain amount of the same toxin injected either with or a short time before it. Such a serum is said to be *anti-toxic.* But in addition to neutralising the toxin of the particular organism, an anti-toxic serum may also protect an animal from infection with the same organism. Thus, an anti-diphtheritic serum prepared by injections of the toxins of the *B. diphtheriæ* also protects an animal from injections of the living virulent *B. diphtheriæ.* On the other hand, it has been observed that the serum of an animal, prepared by gradually injecting increasing doses of a certain living organism, will usually protect another animal from infection by the same living organism when injected under similar conditions. Such a serum is said to be anti-bacterial or anti-microbic, and in relation to the microbe by means of which it has been prepared it is called homologous, but in relation to any other microbe it is considered heterologous. It is sometimes found that an anti-microbic serum has no anti-toxic action. A serum, however, is not necessarily purely anti-toxic or purely anti-microbic, according to the manner in which it is prepared. By injecting living cultures of the *B. diphtheriæ* into a horse, anti-toxins are produced in the serum, probably by the action of the toxins manufactured by the bacillus in the tissues of the horse.

The Origin and Mode of Action of Anti-toxins.—It is not yet known whether an anti-toxin is a bacterial product or a secretion of the cells of the living organism. In support of the hypothesis that anti-toxin is derived from its toxin, Fraser has stated that the quantity of anti-toxin yielded by an animal is proportionate to the amount of toxin introduced. It has, however, been observed that the production of anti-toxin continues after the injection of toxin is suspended, thus, although rabbits actively immunised to tetanus may lose in a short time a quantity of blood equal to their total content, the anti-toxic power of their serum still remains the same as it was before. Salomonsen and Madsen have seen the anti-toxin value of the serum of an animal actually rise when all treatment was suspended. At the present time the balance of opinion seems to be in favour of the hypothesis that anti-toxin is a secretion of the cells of the living organism.

As to the probable nature of the mode of action of anti-toxin, and the explanation why no effects are produced when a mixture of toxin and its corresponding anti-toxin, in suitable proportions, is introduced into an animal susceptible to the toxin, there are three possibilities. Can the anti-toxin break up the toxin and thus destroy its harmful action? On this point there is absolutely no evidence, one way or the other. Is the antagonism between the two substances physiological?—that is, while the toxin might have one effect, the anti-toxin might have an opposite effect, and thus

neutralise the toxic action. Certain experiments by Calmette, Buchner, and Wassermann are adduced in support of this idea, but they are far from conclusive. There remains the third possibility:—Does the anti-toxin combine with the toxin to form a neutral substance having no effect on the tissues? On this point there is a considerable amount of evidence, and there can be no doubt that neutralisation phenomena between toxin and anti-toxin are of the nature of a chemical reaction between the two antagonistic substances; but as to the real nature of what takes place is far from clear. Ehrlich's view on this matter is, that a toxin does not owe its toxicity to one substance, but to a number of toxic agents, all derived from one product of the bacterial protoplasm; these agents are present in two chief forms, a powerful form or true toxin and a weaker form or toxon. Further, he supposes that in the ultimate molecular complex of the true toxin there are two affinities—one set or the haptophorous, which are responsible for combining with anti-toxin, and another set or toxophorous affinities, which are responsible for toxic action. This hypothesis has been much criticised, notably by Madsen and Arrhenius, who, basing their argument on the gradual nature of the neutralisation, compare what takes place between a toxin and anti-toxin with what occurs in the neutralisation of an alkali with a weak acid. According to their view, the partial saturation of a toxin with anti-toxin is not to be explained by supposing that a number of bodies with different affinities and different toxic actions are present in a crude toxin, but by supposing that the toxin and anti-toxin have a weak affinity for each other, and that the reaction is both slow and reversible.

While the controversy as to which of these views is correct is still going on, it must be admitted that there is a tendency among recent workers at this subject to adopt an independent attitude. One of the chief difficulties in the way of accepting the view that the toxin-anti-toxin reaction takes place on ordinary chemical lines is that a mixture of toxin and anti-toxin neutral for one animal species is not necessarily neutral for another species. This suggests that the reaction is not merely one in which two foreign elements take part, but one in which a third element, namely, the animal in which the reaction takes place, must be considered. In this connection Bordet suggests that the smaller molecule of the toxin is entangled in the large molecule of the anti-toxin, very much as a dye is entangled in the structure of a thread without entering into combination with it. According to this view, the relation of the anti-toxin to the toxin is one of adsorption, and an example of the inter-action of two bodies in the colloidal state. At present we know little about the inter-actions of substances in the colloid state, or of the relationships of molecules which are bound to one another without being actually united. It must be admitted that these considerations of the possibility of a colloid element in the reaction are of great importance, and, in spite of the great weight attaching to Ehrlich's experiments and interpretations thereof, suggest caution in accepting absolutely the very definite statements made as to the existence of specific haptophorous and toxophorous groups in the toxin molecule.

Anti-microbic Serum.—As in the reaction against soluble toxins, so in immunity against bacterial invasion changes often occur in the blood-serum of the immunised animal which suggest the presence of substances inimical to the life of the invading micro-organisms; these substances can be used for the passive immunisation of another animal against the specific microbe which originated them. Such a serum is said to be anti-microbic, and may be devoid of any anti-toxic power; if so, an anti-bacterial serum will only save an animal if it helps the animal to kill the infecting

bacteria before these have elaborated one minimal lethal dose of their endo-toxins. Bactericidal sera appear to have two actions on the corresponding bacteria, *i.e.*, a lysogenic and a clumping action. The lysogenic action has been the subject of much experimental research both upon bacteria and red blood-corpuscles, with the result that it is believed to depend on the presence in the anti-serum of a specific substance. Ehrlich, who has applied his " side-chain " theory, as enunciated for the toxin-anti-toxin reaction, to the lysogenic action of sera towards bacteria, assumes that the substances contained in the bacterial protoplasm cause an over-production of the " side-chains " or " immune body," for which they have a special affinity. But in the lysogenic action of serum two substances are concerned. It has been found that if such a serum is heated to 58° C., it loses its lysogenic property ; it, however, regains this action on the addition of a small quantity of serum from a normal animal. But if the fresh serum be heated to 58° C. before being added, it loses its effect. There is, therefore, an unstable ferment-like substance present in normal serum, which is essential to the process of lysogenesis ; this is the so-called " complement." The specific substance called by Ehrlich the " immune body " is more stable, but it cannot act alone ; it forms a link between the bacteria and the complement present in the normal serum. It is a matter of experimental observation that no increase in complement occurs during antibacterial immunisation, and it follows from this that a fresh animal can, by the injection of an immune serum, only be protected against that number of living bacteria which can be killed by the combined action of the amount of complement it contains naturally, plus the amount of immune body with which that complement can combine. Be there ever so much immune body introduced into an animal during an infection, even though that immune body become attached to bacteria in the tissues, the vitality of the bacteria will be unaffected unless sufficient complement be present to act on them through the immune body which they have absorbed. Since, at present, the problem of the artificial supply of complement is unsolved, it follows that, where immune body is introduced in order to assist an animal against bacterial invasion, such immune body is best made available when the animal itself can supply an adequate complement.

The phenomenon of agglutination was first observed by Charrin and Roger, who found that when the *B. pyocyaneus* was grown in the serum of an animal immunised against this organism, the usual diffuse growth through the fluid did not occur, but the bacilli were found in masses at the bottom of the tube. Gruber and Durham also noticed that when to a culture of the *B. typhosus* or *S. choleræ* there was added some of the serum of an animal immunised against the corresponding organism, the bacilli became immobilised and clumped together. Widal then showed that the serum from patients suffering from enteric fever had the power of immobilising and clumping cultures of the *B. typhosus*. Since this observation of Widal's the serum-diagnosis of disease has become established as a reliable procedure. The relation of agglutination to immunity is not yet decided, but it is generally recognised that immunity is independent of the phenomenon. A serum may be strongly bactericidal but weakly agglutinative, and *vice versa*. Moreover, experiment shows that agglutination and bactericidal action in a serum are due to different substances. As to the nature of the agglutination process, we are still somewhat in the dark, but recent work suggests that, as in the toxin-anti-toxin reaction, adsorption of substances in the colloidal condition prevails ; further, the phenomenon may not be due to the presence of a different or special substance

in the serum of an immune animal, but to different properties possessed by a single substance.

In order to explain natural and acquired immunity, Metchnikoff advanced the theory of phagocytosis. According to this theory, the resistance of an animal to bacteria depends on the activity of certain cells called phagocytes, which take up bacteria into their interior, and in many cases destroy them. In the human subject Metchnikoff distinguished two chief varieties of phagocytes, *i.e.*, (*a*) the microphages, which are the polymorphonuclear leucocytes of the blood, and (*b*) the macrophages, which include the larger hyaline leucocytes, endothelial cells, connective-tissue corpuscles, and any of the larger cells that have the power of ingesting bacteria. The migration of the phagocytes towards the bacteria is explained on the hypothesis that the chemical substances elaborated by the bacteria attract the former and exert what is called "positive chemiotaxis." The recent work of Wright and Douglas demonstrating the presence in fresh serum of a substance they call "opsonin," whose function it seems to be to unite with bacteria and, by a process of sensitisation, render them capable of ingestion by the phagocytes, raises the question whether the phagocytic cells are by themselves able to perform a phagocytic function. Whether this is so or not, there can be no doubt that phagocytosis takes place much more readily when certain substances are present. We have not sufficient data to determine the ultimate significance of the opsonic phenomenon; it may be a special manifestation of the reaction operating in bacteriolysis, with a thermostable and a thermolabile element concerned in it, but, in any event, it emphasises the probable complexity of the processes involved in immunity, and suggests that different mechanisms may not only act in different cases, but even in the same case different mechanisms may be combined.

Natural immunity.—At the beginning of this section on immunity we alluded to the fact that it is customary to speak of this condition as being either natural or acquired. So far, we have considered the essential facts only in respect of the acquired protection, and in so doing laid stress upon the circumstance that certain individuals and species present notable degrees of insusceptibility to disease. A closer inquiry into these cases suggests the view that it is doubtful whether we are altogether justified in admitting the existence of any such thing as natural immunity. It is beyond doubt that a few cases do exist which suggest a condition of absolute immunity to infective disease, and to whose body-cells toxins and bacteria are so much inert matter; but may not these instances of apparent natural immunity be equally well explained as merely examples of a very high degree of resistance to infection? For our own part, we are disposed to regard them only in that light, and to consider the difficulties as to how and why that high degree of resistance is maintained to be identical with similar problems explanatory of the recovery of a susceptible animal from a disease or the development of so-called acquired immunity in such an animal. In the present state of our knowledge we need not adhere too rigidly to the conception that the state we call immunity is always either bactericidal or anti-toxic. Our everyday experience, as presented in the case of most common infective diseases, shows it to be neither, but that it is brought about by the coalition of both cells and serum.

ANTHRAX.

This is a fatal acute disease which fortunately affects cattle, horses, sheep, and goats more frequently than man. It is widely spread, appearing with unusual frequency in certain districts, and rendering thereby these localities especially dangerous to herds of cattle. In the ten years 1896–1905, the number of reported outbreaks in Great Britain was 6203, and during this period there has been an apparent marked increase in the disease. Delépine * points out that the distribution of anthrax in the agricultural districts is not determined essentially by geographical situation, climate, density of cattle, population, or extent of manured land; neither does the incidence of the disease among animals correspond at all closely with the distribution of factories manipulating raw animal products.

The clinical aspects of the disease are different in different species of animals; in larger ones it is said to run a comparatively slow course, being accompanied by violent fever, and in most cases, but not always, ends in death. The smaller animals, such as mice and guinea-pigs, succumb to the disease almost without exception, but often without showing any striking symptoms up to the moment of death. On *post-mortem* examination, a conspicuous symptom is the dark, congested, and enlarged spleen. In sheep and cattle there occur hæmorrhagic exudations under the skin of various regions; the exudation forming tumours of a dark to black gelatinous nature.

Anthrax affects man in two forms, external and internal. External anthrax, or, as it is sometimes called, "malignant pustule," has its usual seat on the neck or face, being doubtless due to inoculation. The first local manifestation is the appearance of a papule or vesicle, which develops in the course of a few days into an inflamed indurated mass, with a central black slough. The surrounding tissues and the lymphatic glands are swollen and indurated. In rare instances the disease may remain local, and end in either resolution or suppuration. More commonly, however, constitutional symptoms appear, indicating general infection. Occasionally malignant pustule supervenes upon internal anthrax, which appears to be due to the inhalation or swallowing of the virus. Internal anthrax is chiefly known as affecting wool-sorters, or as the result of the experimental infection of animals, but a case has recently been reported in which the infection may have been by food.†

After a very variable incubation period, ranging perhaps from two to twelve days, the early symptoms of internal anthrax are weariness, depression, chills, restlessness, and a tight feeling across the chest. This stage may last only a few hours, but more usually three to seven days, when graver symptoms set in suddenly. Prostration becomes extreme; pulse and respiration are hurried; temperature rises, but is always marked by sudden remissions, accompanied by perspiration. Even in serious cases recovery may follow, but more commonly death ensues from syncope, pneumonia, or the exhaustion of diarrhœa. In cases of recovery the protection derived from the attack is very slight, if any. This form of anthrax is called wool-sorters' disease, from its prevalence in the Bradford district among men employed in sorting certain foreign wools, particularly those of goats from Van, in Armenia. More or less successful attempts have been made to render the sorting of wools, which experience has shown

* Delépine: Memorandum on Anthrax to the Chester County Council, 1905.

† Teacher: "Primary Intestinal Anthrax in Man," *Lancet*, 1906, vol. i. p. 1306.

to be dangerous, safer, by preliminary disinfection or washing, cleanliness and ventilation of the sorting-rooms, with the use of fan-blasts to carry away the dust generated during the opening and sorting of the bales. To these precautions must be added washing of the hands before eating, and changing of clothes when the work is done.

A microscopic examination of the blood and spleen shows the pathogenic microbe or *Bacillus anthracis*. When examined fresh, these bacilli are non-motile rods, more or less truncated and homogeneous looking, varying a little in size, according to the animal from whence they have been derived. They are usually from 6 to 8 μ long and from 1 to 1·25 μ broad; within the body they do not form spores. The longer bacilli or their chains show, within a common sheath, cubical or rod-shaped, cylindrical, square-cut, stained masses of protoplasm; these are the real bacillary elements. These appearances are more pronounced and noticeable in specimens made from artificial cultures; in some anthrax-thread cultures all the elements constituting a thread are separated one from another by a transverse septum. Anthrax bacilli readily admit of cultivation in feebly alkaline broth, and on gelatin, blood-serum, agar, and potatoes. All the cultures have a more or less characteristic appearance; for instance, in a stab gelatin culture there is first a whitish line in the track of the needle, and from it fine filaments spread out in the gelatin. Occasionally a little isolated spot develops, from which rays extend in all directions, like the silky filaments of thistle-down. The gelatin slowly liquefies and the growth subsides as a flocculent mass. In stroke cultures on gelatin the streak of inoculation is marked after twenty-four to forty-eight hours by a whitish grey line, from which a number of fine whitish threads shoot out horizontally. On agar a thick greyish film is noticeable after two days. After twenty-four hours, in broth at 37° C. there is usually the appearance of irregularly spiral threads suspended in the liquid, and gradually a flaky and flocculent mass forms at the bottom. On potato at 37° C. there occurs a thick felted white mass of bacilli.

Anthrax bacilli, cultivated on the surface of a solid medium, or with free access to air, readily form spores which preserve their vitality for years. The bacilli themselves are readily destroyed by heat or other disinfecting agencies, but the spores are very resistant. As a rule, the bacilli are killed by exposure to 55° C. for forty minutes, spores by steam at 105° C. in ten minutes, and by hot air at 140° C. after four hours. Mercuric chloride, 1 in 10,000, prevents the growth of anthrax bacilli, and 1 in 1000 kills spores in two hours. Formalin, 1 in 15, and cyllin, 1 in 100, destroys the spores in an hour, but to ensure safety the solution of cyllin should be kept at a temperature of 100° F.

Animals can be infected by inhaling or swallowing the spores, but not by the bacilli unless there be some abrasion, such as to allow practically of inoculation. The bacilli are destroyed by the gastric juice, spores are not. Klein has shown a further difference between bacilli and spores by results of inoculation. The former cause a slight and localised malady, the latter a severe constitutional illness which is usually fatal.

The usual mode of infection, so far as man is concerned, is by inoculation; tanners, butchers, and others engaged in handling raw hides being very liable to malignant pustule: it has been suggested that the poison may be carried by flies and other insects. Man may be also infected by inhaling or swallowing spores in the form of dust, as in wool-sorters' disease. Although exact evidence is wanting, it may be assumed that anthrax can be acquired by eating the flesh of diseased animals.

Animals may contract anthrax by the same means as man ; but probably their chief methods of infection are by inhalation and swallowing. A field may become infected with anthrax, and healthy animals grazing on it, after the lapse of months or even years, may acquire the disease. The infection is probably imparted to the superficial layers of the soil by the blood or secretions of affected animals.

With varying degrees of success, attempts have been made to attenuate the virulence of the anthrax bacilli, and by successive inoculations to render animals resistant to the disease. Toussaint, Pasteur, and Chamberland were the pioneers in this field, and for years many thousands of animals have been protected in France by means of their vaccines. Later Sclavo instituted experiments as to the relative strength in immunising effect of the serum of various animals, and found that of the ass to be the most powerful. Sclavo and Marchoux have so developed their combined active and passive immunisation method on practical lines that it has largely replaced that of Pasteur. The advantages of this newer procedure are that it is effective in one day, confers a durable protection, and is also curative.

Prevention resolves itself into the need of obvious precautions for avoiding direct inoculation of a cut or abrasion from either the carcass or the products of an anthrax-affected animal. As regards the trades affected, regulations under section 79 of the Factory and Workshop Act, 1901, now apply in premises where the sorting and combing of specially dangerous wool are carried on. The following are the provisions of Home Office Order No. 1293 on this subject, dated December 12, 1905, made under section 79 of the Factory and Workshop Act, 1901 :—

1. No bale of wool or hair of the kinds named in the Schedules shall be opened for the purpose of being sorted or manufactured, except by men skilled in judging the condition of the material.

No bale of wool or hair of the kinds named in Schedule A shall be opened except after thorough steeping in water.

2. No wool or hair of the kinds named in Schedule B shall be opened except (*a*) after steeping in water, or (*b*) over an efficient opening screen, with mechanical exhaust draught, in a room set apart for the purpose, in which no other work than opening is carried on.

For the purpose of this Regulation, no opening screen shall be deemed to be efficient unless it complies with the following conditions :—

> (*a*) The area of the screen shall, in the case of existing screens, be not less than 11 square feet, and in the case of screens hereafter erected be not less than 12 square feet, nor shall its length or breadth be less than 3¼ feet.
>
> (*b*) At no point of the screen within 18 inches from the centre shall the velocity of the exhaust draught be less than 100 linear feet per minute.

3. All damaged wool or hair or fallen fleeces, or skin, wool or hair, if of the kinds named in the Schedules, shall, when opened, be damped with a disinfectant and washed without being willowed.

4. No wool or hair of the kinds named in Schedules B or C shall be sorted except over an efficient sorting-board, with mechanical exhaust draught, and in a room set apart for the purpose, in which no work is carried on other than sorting and the packing of the wool or hair sorted therein.

No wool or hair of the kinds numbered (1) and (2) in Schedule A shall be sorted except in the damp state and after being washed.

No damaged wool or hair of the kinds named in the Schedules shall be sorted except after being washed.

For the purpose of this Regulation, no sorting-board shall be deemed to be efficient unless it complies with the following conditions :—

> The sorting-board shall comprise a screen of open wirework, and beneath it at all parts a clear space not less than 3 inches in depth. Below the centre of the screen there shall be a funnel, measuring not less than 10 inches across the top, leading to an extraction shaft, and the arrangements shall be such that all dust falling through the screen and not carried away by the exhaust can be swept directly into the funnel. The draught shall be maintained in constant efficiency whilst the sorters are at work, and shall be such that not less than 75 cubic feet of air per minute are drawn by the fan from beneath each sorting-board.

5. No wool or hair of the kinds named in the Schedules shall be willowed except in any

efficient willowing machine, in a room set apart for the purpose, in which no work other than willowing is carried on.

For the purpose of this Regulation, no willowing machine shall be deemed to be efficient unless it is provided with mechanical exhaust draught so arranged as to draw the dust away from the workmen and prevent it from entering the air of the room.

6. No bale of wool or hair shall be stored in a sorting-room; nor any wool or hair except in a space effectually screened off from the sorting-room.

No wool or hair shall be stored in a willowing-room.

7. In each sorting-room, and exclusive of any portion screened off, there shall be allowed an air space of at least 1000 cubic feet for each person employed therein.

8. In each room in which sorting, willowing, or combing is carried on, suitable inlets from the open air, or other suitable source, shall be provided and arranged in such a way that no person employed shall be exposed to a direct draught from any air inlet or to any draught at a temperature of less than 50° F.

The temperature of the room shall not, during working hours, fall below 50° F.

9. All bags in which wool or hair of the kinds named in the Schedules has been imported shall be picked clean, and not brushed.

10. All pieces of skin, scab, and clippings or shearlings shall be removed daily from the sorting-room, and shall be disinfected or destroyed.

11. The dust carried by the exhaust draught from opening screens, sorting-boards, willowing, or other dust-extracting machines and shafts shall be discharged into properly constructed receptacles, and not into the open air.

Each extracting shaft and the space beneath the sorting-boards and opening screens shall be cleaned out at least once in every week.

The dust collected as above, together with the sweepings from the opening-, sorting-, and willowing-rooms, shall be removed at least twice a week and burned.

The occupier shall provide and maintain suitable overalls and respirators, to be worn by the persons engaged in collecting and removing the dust.

Such overalls shall not be taken out of the works or warehouse, either for washing, repairs, or any other purpose, unless they have been steeped over-night in boiling water or a disinfectant.

12. The floor of every room in which opening, sorting, or willowing is carried on shall be thoroughly sprinkled daily with a disinfectant solution after work has ceased for the day, and shall be swept immediately after sprinkling.

13. The walls and ceilings of every room in which opening, sorting, or willowing is carried on shall be limewashed at least once a year, and cleansed at least once within every six months, to date from the time when they were last cleansed.

14. The following requirements shall apply to every room in which unwashed wool or hair of the kinds named in the Schedules, after being opened for sorting, manufacturing, or washing purposes, is handled or stored:—

(*a*) Sufficient and suitable washing accommodation shall be provided outside the rooms and maintained for the use of all persons employed in such rooms. The washing conveniences shall comprise soap, nail-brushes, towels, and at least one basin for every five persons employed as above, each basin being fitted with a waste-pipe and having a constant supply of water laid on.

(*b*) Suitable places shall be provided outside the rooms in which persons employed in such rooms can deposit food and clothing put off during working hours.

(*c*) No person shall be allowed to prepare or partake of food in any such room. Suitable and sufficient meal-room accommodation shall be provided for workers employed in such rooms.

(*d*) No person having any open cut or sore shall be employed in any such room.

The requirements in paragraph (*c*) shall apply also to every room in which any wool or hair of the kinds named in the Schedules is carded or stored.

15. Requisites for treating scratches and slight wounds shall be kept at hand.

16. The occupier shall allow any of H.M. Inspectors of Factories to take at any time, for the purpose of examination, sufficient samples of any wool or hair used on the premises.

17. No bale of wool or hair of the kinds named in the Schedules shall be opened otherwise than as permitted by paragraph 1 of Regulation 1, and no bale of wool or hair of the kinds named in Schedule A shall be opened except after thorough steeping in water.

If on opening a bale any damaged wool or hair of the kinds named in the Schedules is discovered, the person opening the bale shall immediately report the discovery to the foreman.

18. No wool or hair of the kinds named in Schedule B shall be opened otherwise than as permitted by Regulation 2.

19. No wool or hair of the kinds named in the Schedules shall be sorted otherwise than as permitted by Regulation 4.

20. No wool or hair of the kinds named in the Schedules shall be willowed except as permitted by Regulation 5.

21. Every person employed in a room in which unwashed wool or hair of the kinds named in the Schedules is stored or handled shall observe the following requirements:—

(*a*) He shall wash his hands before partaking of food, or leaving the premises.

(*b*) He shall not deposit in any such room any article of clothing put off during working hours.

He shall wear suitable overalls while at work, and shall remove them before partaking of food or leaving the premises.

(c) If he has any open cut or sore, he shall report the fact at once to the foreman, and shall not work in such a room.

No person employed in any such room or in any room in which wool or hair of the kinds named in the Schedule is either carded or stored shall prepare or partake of any food therein, or bring any food therein.

22. Persons engaged in collecting or removing dust shall wear the overalls as required by Regulation 11.

Such overalls shall not be taken out of the works or warehouse either for washing, repairs, or any other purpose, unless they have been steeped over-night in boiling water or a disinfectant.

23. If any fan, or any other appliance for the carrying out of these Regulations, is out of order, any workman becoming aware of the defect shall immediately report the fact to the foreman.

Schedule A.

(Wool or hair required to be steeped in the bale before being opened.)

1. Van Mohair.
2. Persian Locks.
3. Persian or so-called Persian (including Karadi and Bagdad) if not subjected to the process of sorting or willowing.

Schedule B.

(Wool or hair required to be opened either after steeping or over an efficient opening screen.)

Alpaca.
Pelitan.
East Indian Cashmere.
Russian Camel Hair.
Pekin Camel Hair.
Persian or so-called Persian (including Karadi and Bagdad) if subjected to the process of sorting or willowing.

Schedule C.

(Wool or hair not needing to be opened over an opening screen but required to be sorted over a board provided with downward draught.)

All Mohair other than Van Mohair.

We consider this Order excellent so far as it goes, but it errs in failing to lay down any clear rules or instructions how the raw material can be rendered reasonably safe before being handled by the workman. In view of our modern knowledge of steam disinfection, it seems desirable that the whole question of its application to the disinfection of horse-hair, bristles, and other like material should be laid down. The more recent Regulations of the Home Office recognise this practice. Prolonged experiments in Ge many have shown that so long as the pressure does not exceed 2¼ lb. above atmospheric pressure, equivalent to a temperature of 220° F., even tail-hair will suffer no damage. "Regulations requiring this or either boiling (1) for at least two hours in water, or (2) for at least a quarter of an hour in a 2 per cent. solution of potassium permanganate and subsequent bleaching in a 3–4 per cent. solution of sulphurous acid, have been required in all horse-hair and brush factories in Germany since 1899; and their enforcement has reduced markedly the number of cases of anthrax in the industries named. Exception from the process of disinfection is allowed in the case of such material as cannot, according to present experience, be subjected to disinfection without serious damage, or which, as in the case of white hair, undergoes alteration in colour. In this country considerably higher pressures than those adopted in Germany have been systematically used in the case of curled hair. Success, however, is to be obtained only by a minute attention to detail both in the construction of the apparatus and skilled supervision during working." *

* Legge: Report on the Incidence of Anthrax in the Manipulation of Horse-hair and Bristles, Home Office, March 1906.

There are obvious difficulties in the way of installing expensive disinfecting apparatus in individual works, but were this procedure centralised at warehouses at ports of importation it would be a simple matter to protect the limited number of persons so exposed to risk, and the necessity for formal regulations in factories and workshops in respect of these matters might in great measure be obviated. If steam disinfection be deemed too likely to damage wool and hair, steeping of the loosened material in such well-known disinfectants as kerol and cyllin, or even izal, might be adopted. Klein has shown that a bath of 1 per cent. of cyllin maintained at a temperature of 135° F., with a period of contact of one and a half hours, is efficient for rendering raw wool, horse-hair, bristles, &c., safe, without damage to the material.* These appear to be the most rational and necessary means of dealing with this question, and if officially adopted would relieve the manufacturer of his present grave responsibility and save the employees from the dread and danger of an almost certainly fatal disease. A further step in the right direction would be the inclusion of anthrax amongst the diseases notifiable under the Infectious Diseases Notification Act, 1889, thereby enabling health authorities to follow up and deal promptly with infected material.†

BERIBERI.

This disease appears to be a specific form of multiple peripheral neuritis. It is endemic in most tropical and sub-tropical climates. Scheube and Baetz were the first to point out that beriberi was probably a peripheral neuritis, and Pekelharing and Winkler have supported this view.

Geographical Distribution.—Beriberi has been described as occurring in India, the Malay Archipelago, Brazil, Western Australia, Japan, Havana, the Sandwich Islands, and the West Coast of Africa. It has also appeared in the Richmond Asylum in Dublin. It has a predilection for certain localities, and has often broken out in jails, schools, and ships as the result of overcrowding. In connection with ship beriberi, it is noticeable that it is common in Swedish and Norwegian vessels, notwithstanding the general good sanitary administration of these ships.

Influence of Climate, Sex and Age.—In countries which are hot all the year round, beriberi may appear at any time, but it is chiefly met with in the wet cool months. In sub-tropical countries the disease is most common in the warm season. It attacks both sexes. It is rare in childhood and old age, developing most usually between the ages of fifteen and thirty. Occupation appears to have no influence on the incidence of beriberi, though on shipboard it is usually limited to the occupants of the forecastle. The mortality varies extremely. In some epidemics it has been as high as 30 per cent. of the persons attacked; in others as low as 5 per cent.

Etiology.—Beriberi assumes various forms; in a large proportion of cases there is paraplegia, chiefly affecting the extensor muscles of the lower extremities. Œdema is one of the leading signs, and, unlike the œdema of cardiac and renal disease, it does not begin about the ankles, but appears along the inner side of the tibia. Sometimes general anasarca is observed, while dilatation of the right side of the heart is frequent and death from

* Klein: "The Disinfection of Anthrax Spores," *The Sanitary Record*, December 13, 1906, p. 327.

† Hanna: "Anthrax and Imported Animal Products," *Public Health*, April 1907, p. 439.

syncope not uncommon. It is probable these symptoms indicate merely a late manifestation of an antecedent and probably extinct infection, therefore any attempt to determine the precise cause of the disease must be made at a very early period and before the typical nervous symptoms have set in.

Various views have been put forward as to the causation of beriberi, and these divide themselves into those which assume the cause to originate outside and those which deem it to be produced inside the body of the patient. Under the first group we get the following suggestions as to cause :—(1) nitrogen starvation, (2) arsenical poisoning, (3) chronic oxalic acid poisoning, (4) chronic malnutrition from some defect in food, such as rice, (5) absorption of some poison emanating from soil or place, and (6) personal infection. In the second group the hypotheses involve the invasion of the body by some microbe which may or may not produce a local lesion. The local lesions which have been described are either a gastro-duodenitis or a pharyngitis and other throat lesions. This view has been strongly advocated by Hamilton Wright, who believes beriberi to be an intoxication due to products formed by a large bacillus living in the duodenum. Pekelharing ascribed the disease to a microbial infection by a staphylococcus ; Okata deemed it due to a micrococcus found in the urine ; while Daniels suggests that it is due to a protozoon gaining access to man by the bites of lice. Recently Hewlett and De Korté * have adduced some evidence that possibly the disease is a protozoan infection in which the urine is the source of infection. Until stronger evidence is produced in support of these various suggestions, they must be considered as mere hypotheses.

Takaki † was the first to propound the nitrogen-starvation theory, and certainly his improvements in the dietaries of Japanese soldiers and sailors lend some support to the view ; but they are not quite convincing, especially when we remember that nitrogen starvation is common among the poor of all countries and yet beriberi is limited in its distribution. Ross suggested that arsenic might be the cause of the peripheral neuritis so common in beriberi, but the hypothesis is weakened by the remarkable absence in beriberi of the skin lesions of true arsenical poisoning. Treutlein ‡ calls attention to some observations of Eijkmann, who found that a clinical picture closely resembling human beriberi could be produced in fowls by feeding them with decorticated rice. Similar results were obtained by Maurer, who fed fowls with oxalic acid. These observations have been confirmed and extended by Treutlein, who attributes the pathological changes to a removal of calcium from the affected tissues owing to the action upon them of the oxalic acid or sodium oxalate introduced by feeding, or of the oxalic acid produced from rice-meal by the agency of micro-organisms present in the crop of the fowls. Careful criticism of the ground or place and personal infection theories, as well as that suggesting the action of some microbe, shows the available evidence to be weak ; while all experience shows that the communicability of beriberi from man to man to be so slight that the influence of personal infection must be small.

The curious association, amounting almost to a limitation, of beriberi to people who are large consumers of rice has long suggested the idea that

* Hewlett and De Korté : "On the Etiology of Beriberi," *Brit. Med. Journal*, 1907, vol. ii. p. 201.

† Takaki : "The Preservation of Health amongst the Personnel of the Japanese Navy and Army," *Lancet*, 1906, vol. i. pp. 1369 and 1451.

‡ Treutlein : *Verhandlungen der physikalisch-medicinischen Gesellschaft zu Würzburg*, 1906, Bd. 38, No. 11.

the persistent consumption of that cereal played an important part in the causation of the disease. Some recent observations by Fletcher,* conducted at the Kuala Lumpur Lunatic Asylum in the Federated Malay States, indicate that persons fed on "cured" rice do not develop or suffer from beriberi, while others living under the same conditions, but fed upon "uncured" rice, suffer severely from the disease. By uncured rice is meant the ordinary white rice sold in the Malay States as Rangoon or Siam rice, which is eaten by all classes except Indians and Malays. This rice, after being harvested, is taken to the mills, where it is husked and cleaned before being sold to the rice merchants. Cured rice is brownish in colour, and forms the staple food of Indians and Cingalese. The great difference between this rice and the uncured variety is that the former is boiled and dried before being milled. The white, or uncured, rice is stored unboiled after being husked; the brown, or cured, rice is stored after being boiled and then husked. Although Fletcher's observations are limited, still the reported facts are so clear that it is difficult to avoid the conclusion that uncured rice is, either directly or indirectly, a cause of beriberi. It remains to be proved whether the cause is a poison contained in the rice or whether there is something essential to the human economy which is supplied by the cured rice, whilst it is absent in the uncured. We have been unable to obtain an analysis of the two kinds of rice, but it is probable that the cured rice contains a larger quantity of protein matter than the uncured. If this be the case, the deficiency of protein in the diet may be the actual cause of the disease, or, what is more likely, the lack of nutritive matter in the rice may induce a condition in the man which renders him an easy prey to some external agency, bacterial or protozoal, which is the actual cause of beriberi. Apart from these views, it may be that the infective agent is a constant parasite on rice, and that the apparent beneficial results following the consumption of "cured" rice is to be explained by the fact that the process of curing by means of heat destroys the infective agent, which otherwise would reach man by means of rice.

Prevention.—The first essential is the provision of a liberal dietary among the susceptible class. Where rice is the staple article of food, the so-called "cured" variety should alone be issued. When cases of the disease have declared themselves, removal from the affected place, home, institution, or ship is of the first importance. This should be followed by thorough disinfection, which should ensure the destruction of vermin. Although the existence of any degree of infectivity in beriberi is open to doubt, still, in the absence of direct proof to the contrary, it is as well to act as though it were an infective disease; for these reasons, it is advisable in endemic areas to keep all newcomers separate, as far as possible, till it is known whether they are the subjects of beriberi or not. In the lines of coolies or homes of the poor in tropical countries, overcrowding must be strictly forbidden.

CEREBRO-SPINAL FEVER.

Although this country has hitherto been remarkably free from epidemics of cerebro-spinal meningitis, the disease prevails here sporadically, and the recent occurrence of a considerable number of cases in Glasgow and Belfast is a warning that, in overcrowded centres, an explosive outbreak may occur at any time.

* Fletcher: "Rice and Beriberi," *Lancet*, 1907, vol. i. p. 1776.

In a Memorandum on this disease issued in 1905, and again in February 1907, the Local Government Board adopt the late Dr. Netten Radcliffe's definition of the disease in the following words :—

An acute epidemic disease, characterised by profound disturbance of the central nervous system, indicated at the onset chiefly by shivering, intense headache or vertigo, or both, and persistent vomiting ; subsequently, by delirium, often violent, alternating with somnolence or a state of apathy or stupor ; an acutely painful condition with spasm—sometimes tetanoid—of certain groups of muscles, especially the posterior muscles of the neck, occasioning retraction of the head ; and an increased sensitiveness of the surface of the body. Throughout the disease there is marked depression of the vital powers ; not unfrequently collapse ; and in its course an eruption of vesicles, petechial, or purpuric spots, or mottling of the skin is apt to occur. If the disease tend to a recovery, the symptoms gradually subside without any critical phenomena, and convalescence is protracted ; if to a fatal termination, death is almost invariably preceded by coma. After death the enveloping membranes of the brain and spinal cord are found in a morbid state, of which the most noticeable signs are engorgement of the blood-vessels, usually excessive, and an effusion of sero-purulent matter into the meshes of the pia mater and beneath the arachnoid.

To the clinical manifestations of the disease, indicated in this definition, may be added the presence of Kernig's sign and of *tache cérébrale.*

Mortality.—The mortality varies ; in some outbreaks 80 per cent. of the cases have died, in others only 20 per cent. have proved fatal. The disease has a wide distribution, and it has frequently occurred, even in recent years, in neighbouring countries. Thus in Hamburg in 1896, there were thirty cases with twenty-six deaths ; in Sweden in the same year there were 165 cases with 74 deaths ; and 66 cases were reported in Denmark, and 409 cases in Italy. In Glasgow, during 1906, there were 213 cases notified, and of these 148 died, being a death-rate of 69 per cent. In England and Wales, the average number of deaths from this disease during the last ten years has been 46, but the number has been increasing steadily ; in 1896 the total was 11, in 1905 it was 127.

Influence of Sex, Age, and Race.—It is difficult to find any difference in regard to the incidence of the disease upon the two sexes. As regards age, it usually attacks those approaching puberty, or in early adult life ; it has been known, however, to occur in persons of all ages, though certainly rare among those beyond middle life. The evidence in respect of race indicates it to make no distinctions.

Effects of Climate and Season.—In all countries in which it has been observed as an epidemic, this has usually occurred in either winter or spring ; that is, in the coldest seasons of the year.

Etiology.—Our knowledge on this matter dates from 1887, when Weichselbaum * published the results of the bacteriological investigation in eight cases of acute meningitis. In two of these cases he found the pneumococcus to be the exciting cause, but in the remaining six a micrococcus wholly different from the pneumococcus was present in pure culture, both in the cerebro-spinal exudate and in the ventricles of the brain. To this micro-organism he gave the name *Diplococcus intracellularis meningitidis.* Later investigations have confirmed Weichselbaum's conclusions, with the result that at the present day it, or, as this micro-organism is sometimes termed, the *meningococcus*, is generally admitted to be the chief, and apparently the sole, bacteriological factor in epidemic cerebro-spinal meningitis.

For our more precise knowledge regarding the cultural characters of the meningococcus we are indebted to Gordon,† who describes this micro-

* Weichselbaum : *Fortschr. d. Med.*, 1887, vol. v. Nos. 18 and 19. *See also* his article on the Meningococcus in Kolle u. Wassermann's *Pathogenen Mikro-organismen*, Jena, 1903, vol. iii. p. 256.

† Gordon : Report to the Local Government Board on the Micrococcus of Epidemic Spinal Meningitis and its Identification, London, 1907.

organism as an obligatory aerobe, growing best on ordinary peptone agar to which has been added 5 per cent. of ascitic fluid and 0·3 per cent. of nutrose. It also grows well in broth containing 10 per cent. of fresh ascitic fluid. The optimum development in these media occurs at 36°–37° C., and at 42° C. growth is arrested. The meningococcus will not grow at a temperature below 25° C. Preparations made from cultures show that it occurs as single cocci, as diplococci, in small groups, and occasionally in tetrads. It belongs to the staphylococcus group, as it never forms chains ; another feature is, it is Gram-negative. On nutrose-ascitic agar, the colonies of the meningococcus, after twenty-four hours' culture at 37° C., are smooth, moist, grey, translucent, circular, or oval discs with regular outline. These colonies resemble those of young colon bacilli, and are quite different from the granular, opaque colonies of staphylococcus albus. Unlike those of many other gram-negative cocci, these colonies of the meningococcus exhibit no yellow colour. Two micro-organisms present some general similarities to the meningococcus ; these are the *Gonococcus* and the *Micrococcus catarrhalis*. Both these are Gram-negative, but certain fermentation reactions in sugars will be found a useful aid in their differentiation. In saccharose, both the meningococcus and gonococcus give negative reactions ; in glucose, maltose, and galactose, the meningococcus gives positive reactions, while the gonococcus does so only in glucose and galactose ; the M. catarrhalis fails to ferment any one of these four sugars. The fermentation, when positive, only proceeds to the production of acid, but no gas.

Diagnosis and Prevention.—The difficulties in the way of detecting early cases of this disease are notorious. On this point, the Memorandum of the Local Government Board, which has already been referred to, makes the following observations :—

Local prevalence of a malady distinguished by the foregoing features would, it may be presumed, lead to early recognition of its true nature. But, while these features are characteristic of cerebro-spinal fever of typical and severe sort, experience has taught us that this fever may, and does, appear in milder or in anomalous forms which render identification difficult and which lead to its being mistaken for other ailments of more common occurrence in this country. Illustration of this is afforded by certain localised outbreaks of cerebro-spinal fever in the eastern counties in 1890, where this disease was generally mistaken for sunstroke or for enteric fever, or was looked upon as a new form of illness ; by the prevalence of what would seem to have been cerebro-spinal fever in Northamptonshire in 1890–91, where the malady was for the most part diagnosed as pneumonia or as sore-throat ; and by the occurrence of cerebro-spinal fever in Irthlingborough in the present year, where many of the persons attacked were regarded as suffering from influenza. In these anomalous forms of cerebro-spinal fever, many or even most of the symptoms associated with the recognised type of the disease may be absent, while, in mild cases, they may be so slight or of such brief duration as to escape notice. It is, however, for such cases that it is necessary to be on the outlook, whether in relation with a definite occurrence of cerebro-spinal fever in a locality, or by reason of the prevalence in a particular neighbourhood of illness not clearly referable to definable cause. In these circumstances there would be advantage in the local Medical Officer of Health endeavouring to secure, by arrangement with the medical men practising in his district, information as to the existence of cases of the kind in question.

Failure to recognise cerebro-spinal fever is also apt to happen when the malady is of the "fulminant" variety, in which death ensues rapidly. In these instances the disease has been mistaken for typhus fever, idiopathic tetanus, or malignant measles.

An important aid to diagnosis may be found in examination of cerebro-spinal fluid, withdrawn from the lower part of the spinal canal by lumbar puncture, for the presence of the "diplococcus meningitidis intracellularis" of Weichselbaum ; a micro-organism which is now generally regarded as the specific cause of cerebro-spinal fever.

Whether cerebro-spinal fever is spread by direct infection from person to person is matter of uncertainty ; indeed, there is as yet no definite knowledge as to the way or ways in which its transmission may take place. Since, however, the possibility of direct personal infection cannot, on the evidence available, be excluded, it will be wise to endeavour to secure, as far as practicable, the isolation of the sick from the healthy. It will also be advisable to apply

suitable measures of disinfection to premises that have been occupied by the sick and to articles that may have been in relation with them.

In view of the fact that the presence of Weichselbaum's diplococcus has been observed in the mucus of the nose and mouth, not only of the sick, but also of those attending on the sick, there may be advantage in resorting to periodical ablutions of the nasal and buccal passages of the sick and their attendants.

This Memorandum practically summarises our present knowledge of this obscure disease, and it must be owned that, until we understand better the channels of infection, our efforts at prevention can be but empirical. At present, one may say that, in all probability, infection takes place by the respired air; in this case, the most likely method would be by a sort of droplet infection. But, how does the infective material reach the meninges? Direct infection through the ethmoid cells is hardly conceivable; still, while a lymphatic infection is by no means excluded, the hæmatogenous path seems the more likely. Whilst the possibility of the entrance of the meningococcus through the tonsils or abraded buccal surfaces appeals to us very forcibly as a probable means of infection, we cannot overlook the possibility of food infection, particularly among young children.

To control the spread of this disease is a most difficult problem, and likely to be a failure until we can discover and deal efficiently with the intermediary or carrier of infection. The procedure which offers the most reasonable chance of success is the systematic bacteriological examination of swabs taken from the posterior nares of all members of households in which a case has occurred. The noses and throats of all these possible carriers of meningococci should be sprayed with chlorine water at intervals of two days for a week. This action may be supplemented by the sucking of formamint lozenges, which constitute a valuable accessory in dealing with intermediaries or infection carriers.

CHICKEN-POX.

It was only towards the end of the last century that this disease was clearly distinguished from small-pox; but beyond a certain superficial resemblance there is nothing in common between the two diseases. Chicken-pox occurs as an epidemic, which very often coincides with epidemics of small-pox, and adds to the difficulty of diagnosis of mild cases of the latter. Persons of all ages are liable to attack, but children more so than adults. The mortality is practically *nil*, though the Registrar-General annually records a few deaths from chicken-pox; how far these fatal cases may be set down to unrecorded deaths from small-pox is difficult to decide; possibly a large proportion may be so, without error.

The incubation period has been variously estimated to be from four to twenty-eight days; recent opinion sets it down at about fourteen days, for which reason the Association of Medical Officers of Schools insist upon a quarantine of eighteen days before re-admission to school, after exposure to infection.

The characteristic vesicular eruption appears without any previous sickness, or at most with only some twenty-four hours of fever or malaise. It begins on any part of the body, and is added to irregularly by fresh crops for four or five days, during which time the constitutional symptoms are most irregular. The vesicles are not usually umbilicated, but this is not a reliable point for diagnosis, as among them are often some which are so. The vesicles consist of a single cavity, with a very thin covering, and with little or no hardness at the base. About the third day, the clear watery

contents of the vesicles become turbid; within a week a thin crust forms which eventually falls off and leaves no cicatrix unless sores have been caused by irritation. The infection of chicken-pox is active from the very first, and is readily imparted by contact or by means of fomites. The mode in which it is given off is unknown, but the breath is the most probable cause of infection. As in small-pox, the length of infectivity will depend on the falling off of the crusts, which usually become detached in parts rather than entire.

Attempts have been made to inoculate from the vesicles, but without success. Chicken-pox and small-pox are not mutually protective.

CHOLERA.

It is usual to speak of cholera having its endemic area in certain parts of India, more particularly the delta of the Ganges, but it is possible that other parts of Asia are also its endemic home.

As an epidemic, cholera has appeared in England four times, namely, in 1831–2, 1848–9, 1853–4, and 1865–6; the disease having on these occasions slowly spread from India. On several other occasions the disease has invaded Europe, but failed to reach England. In July 1831 infection was carried to the Medway by ships from Riga; later in the same year it broke out at Sunderland and other northern ports, as a result of importation by ships from Hamburg. In the course of the next year it was extensively prevalent in Great Britain, extending later to Canada and the United States. In 1848 London was infected from Hamburg in September, and Hull and Sunderland in October from the same port; from these centres the disease at once spread. During the winter of 1848–9 cholera abated, but in the spring of 1849 it broke out again wth increased vigour, finally disappearing in December, having caused 53,293 deaths, besides a heavy diarrhœal mortality, part of which was probably due to cholera. In 1854 it was again severely epidemic in Great Britain, having been once more imported from Germany. During this year cholera caused over 20,000 deaths in England and Wales.

The fourth epidemic invasion of Great Britain, in 1865, had a somewhat different history. Starting from the basin of the Ganges in 1863, cholera was carried by ships to South Arabia; it next broke out among the Mecca pilgrims, by whom it was carried to many places, among them Suez. From Egypt it spread along the Mediterranean littoral, extending through the whole of Southern and Central Europe. England was infected through Southampton from Alexandria during August, but only to a small extent. In the following spring the disease was again repeatedly imported from the Continent, and during that year something like fifteen thousand people died from cholera in the whole of England. Since then the disease has not prevailed as an epidemic in this country, though frequently imported and prevalent in various parts of Europe, more especially since 1884. During this year (1884) cases of cholera were three times brought in ships to England, but no spread of the disease occurred. The same thing occurred again in the two next following years. In 1890 a recrudescence of cholera advanced from Persia and Central Asia, culminating in the infection of Hamburg on August 23, 1892. The mortality in Europe during the gradual extension of the disease westward in 1892 was very great. Two days after Hamburg was declared infected, three cases of cholera from that city arrived in London, and by the middle of October quite thirty cases had been brought to this

country; but in no instance, so far as is known, did the disease extend to any person other than those arriving from abroad. Cholera was also epidemic in Europe during 1893, and continued to prevail in 1894 and 1895. The countries which chiefly suffered in the last two years were Russia, Austria, and Turkey. The principal area of cholera prevalence was, however, Russia, more especially the portions of the country adjoining the frontiers of Austria and Germany. Across the frontiers of these countries the disease was carried again and again by travellers.

Although at one time or another cholera has extended widely over the earth's surface, still it has, so far, never invaded Australia, the Pacific Islands, St. Helena, Ascension, the east coast of Africa south of Delagoa Bay, Iceland, the Färöe Islands, the Hebrides, Orkney, and Lapland (Hirsch). Apart from the possible enjoyment of perhaps special sanitary advantages, more particularly pure and wholesome water-supplies, local exemptions from cholera are mainly due to the relatively little communication between the places in question and the continent of India, or other centres of endemic prevalence.

Mortality.—This is often enormous. The case mortality ranges commonly from 40 to 70 per cent.; our Indian experiences show it to be greater at the beginning than during the later stages of an outbreak.

Influence of Climate, Season, and Temperature.—Warmth is a predisposing condition of great importance, but it is not, in itself, sufficient to cause an outbreak of cholera, nor does cold necessarily arrest it. That a certain degree of heat favours the activity of the poison is sufficiently evidenced by the fact that in Europe the disease has generally attained its greatest prevalence from June to August, subsiding during the winter, often only to reappear in the following summer. There are, however, exceptions to this general rule; even in India the seasonal curve of cholera prevalence is not coincident always with that of temperature. As regards rainfall, we believe its influence on cholera prevalence to be limited to its direct effect upon water-supplies; that is, either favouring the scouring and cleansing of river channels, or their pollution by washing in surface filth from the banks.

Influence of Race, Sex, and Age.—There is a general consensus of opinion among authorities that the incidence and severity of cholera are greater among negroes than Europeans, but as to the relative susceptibility of other races little is known. The evidence as to influence of sex is imperfect; what there is, indicates that the general mortality is greater among males than females, but that the case fatality is in excess for females up to twenty-five years of age, after which it is greater for males. As regards age, apart from sex, the actual number of deaths is much greater during the extremes of life than during the middle periods. This is very much what might be expected.

Etiology.—General sanitary defects, no doubt, are conducive to cholera prevalence and mortality, as determining the points of attack, especially by inducing a lowered standard of health with diminished powers of resistance, and by specifically fouling the air, soil, and water. Hence, the disease attacks more especially the poorest quarters of towns. The poison doubtless gains access to the system by swallowing, more rarely by inhalation, the incubation period being from a few hours to three days; though it may apparently reach as much as ten days. The infection is given off in the discharges from the bowels, and possibly in the vomit also. These may infect, as already explained, either water, milk, soil, or fomites.

Etiologically, cholera exhibits some connection with, and likeness to,

diarrhœa. Marked prevalence of the latter disease is often noticed as a precursor of the former; while both appear to be associated with filth, and to be influenced by heat and certain physical conditions of the soil, more particularly porosity.

That cholera ultimately depends upon micro-organic life processes has been provisionally assumed in the preceding remarks. Since Koch discovered a comma bacillus in the evacuations and intestines of cholera patients, and adduced evidence in support of the view that this organism is the cause of the disease, the *comma bacillus* has become generally to be regarded as the real infective agent of cholera—though there have not been wanting competent critics who question the pathogenesis of this bacillus.

Cholera bacilli appear as rods curved in the direction of their long axis so as to resemble a comma in figure, hence the name "comma bacillus." They have a twist in addition to this curve, so that they represent a kind of spiral bacteria; when connected in chains they give rise to corkscrew forms. A flagellum can be demonstrated at one end, but no spore formation. These commas feebly resist chemical re-agents, being destroyed by the acid of the gastric juice, and refusing to grow upon feebly acid gelatin. They are killed in an hour by a temperature of 55° C., and much more rapidly at higher temperatures, while drying causes speedy loss of the power of development.

The precise parts taken by air, milk, soil, and water in the diffusion of cholera have already been considered elsewhere. Of these, brief mention need only again be made in respect of the two latter. The whole course of not only the last great epidemic of cholera in Europe in 1892, but of all others, especially in England, shows that the disease is propagated mechanically, and that the influence of the soil is quite subsidiary. On the other hand, soil may, and doubtless does, serve as a medium in which the cholera virus can survive outside the human body. Confirmative of this view are the striking instances, from India, in which fresh sand, from the banks of rivers used as bathing-places by the infected, placed in filters, has been the means apparently of giving rise to outbreaks of cholera to those partaking of the water filtered through it.

As regards water, the earlier objections to the possibility of cholera commas conveying the disease, because of their alleged inability to survive any length of time in water, are no longer tenable. Many observers have shown that cholera commas not only live but multiply in drinking waters. Although results on this point have been conflicting and difficult fully to reconcile, still the inference is undeniable that cholera can be and is conveyed and diffused by drinking water more frequently than by anything else.

Striking as are the historical facts in connection with the relation of cholera to water, we do not desire to suggest that water-carriage constitutes, even in Europe, the only means of the propagation of cholera. We wish specially to emphasise the fact that experience has proved that polluted water-supplies have played at all times a conspicuous part in the dissemination of the disease. At the same time, the behaviour of cholera, not only in India but in Europe, seems to require for its explanation a theory of the ability of the cholera organism or virus to maintain life, or even pass through some phase of its life outside the animal body, most probably in the soil. It is not unlikely that it is capable, under certain circumstances, of escaping from the soil and infecting human beings, either directly or by fastening on to food. In connection with this point, Sims Woodhead has pointed out that the generally accepted cholera organism, or comma bacillus, when grown anaerobically, gains increased virulence, but largely loses its power of

resistance to germicidal agents. Conversely, when grown aerobically, it largely loses its virulence, but gains in resisting power. "Its cultivation in the bodies of human hosts, therefore, while augmenting its virulence, does not tend to preserve that section of a given crop which has taken to colonise in the human subject. On the other hand, its aerobic existence outside the human body, while diminishing its ability for immediate harm to human beings, increases its ability of maintaining itself, and of migrating from the soil to man when favourable conditions shall come round." These facts further may explain why cholera displays so little tendency to spread immediately from person to person, but yet readily disseminates itself by fomites, such as infected body-linen.

Prevention.—Our course of action and duties in this respect cannot be more tersely stated than in the following extract from a Memorandum, issued in 1892 to the Sanitary Authorities of England and Wales, by the Medical Officer of the Local Government Board :—

Cholera in England shows itself so little contagious, in the sense in which small-pox and scarlatina are commonly called contagious, that, if reasonable care be taken where it is present, there is almost no risk that the disease will spread to persons who nurse and otherwise closely attend upon the sick. But cholera has a certain peculiar infectiveness of its own, which, *where local conditions assist*, can operate with terrible force, and at considerable distances from the sick. It is characteristic of cholera (and as much so of the slight cases where diarrhœa is the only symptom of the disease in its more developed and alarming forms) that *the matters which the patient discharges from his stomach and bowels are infective.* Probably, under ordinary circumstances, the patient has no power of infecting other persons except by means of these discharges ; nor any power of infecting even by them except in so far as these matters are enabled to taint the food, water, or air which people consume. Thus, when a case of cholera is imported into any place, the disease is not likely to spread unless in proportion as it finds, locally open to it, certain facilities for spreading by *indirect infection.*

In order rightly to appreciate what these facilities must be, the following considerations have to be borne in mind :—First, that any choleraic discharge, cast without previous thorough disinfection into any cesspool or drain, or other depository or conduit of filth, is able to infect the excremental matters with which it there mingles, and probably, more or less, the effluvia which those matters evolve ; secondly, that the infective power of choleraic discharges attaches to whatever bedding, clothing, towels, and like things have been imbued with them, and renders these things, if not thoroughly disinfected, capable of spreading the disease in places to which they are sent for washing or other purposes ; thirdly, that if, by leakage or soakage from cesspools or drains, or through reckless casting out of slops and waste water, any taint (however small) of the infective material gets access to wells or other sources of drinking water, it can impart to enormous volumes of water the power of propagating the disease. When due regard is had to these possibilities of indirect infection, there will be no difficulty in understanding that even a single case of cholera, perhaps of the slightest degree, and perhaps quite unsuspected in its neighbourhood, may, *if local circumstances co-operate*, exert a terribly infective power on considerable masses of population.

The dangers which have to be guarded against as favouring the spread of cholera infection are particularly two. First, and above all, there is the danger of WATER-SUPPLIES, which are in any (even the slightest) degree tainted by house refuse or other like kind of filth ; as where there is outflow, leakage, or filtration from sewers, house drains, privies, cesspools, foul ditches or the like into springs, streams, wells, or reservoirs, from which the supply of water is drawn, or into the soil in which the wells are situate—a danger which may exist on a small scale (but perhaps often repeated in the same district) at the pump or dip-well of a private house, or, on a large or even vast scale, in the case of public water-works. And secondly, there is the danger of breathing AIR which is foul with effluvia from the same sorts of impurity.

Information as to the high degree in which those two dangers affect the public health in ordinary times, and as to the special importance which attaches to them at times when any diarrhœal infection is likely to be introduced, has now for so many years been before the public that the improved systems of refuse removal and water-supply by which those dangers are permanently obviated for large populations, and also the minor structural improvements by which separate households are secured against them, ought long ago to have come into universal use.

So far, however, as this wiser course has not been adopted in any sanitary district, security must, as far as practicable, be sought in measures of a temporary and palliative kind.

(*a*) Immediate and searching examination of sources and conduits of water-supply should be made in all cases where drinking water is in any degree open to the suspicion of impurity ; and the water both from private and public sources should be examined. Where pollution is discovered, everything practicable should be done to prevent the pollution from con-

tinuing, or, if this object cannot be attained, to prevent the water from being drunk. Cisterns should be cleaned, and any connections of waste pipes with drains should be severed.

(*b*) Simultaneously, there should be immediate thorough removal of every sort of house refuse and other filth which has accumulated in neglected places; future accumulations of the same sort should be prevented; attention should be given to all defects of house drains and sinks through which offensive smells can reach houses; thorough washing and limewashing of uncleanly premises, especially of such as are densely occupied, should be practised again and again.

It may fairly be believed that, in considerable parts of the country, conditions favourable to the spread of cholera are now less abundant than in former times; and in this connection, the gratifying fact deserves to be recorded that during recent years enteric fever, the disease which in its methods of extension bears the nearest resemblance to cholera, has continuously and notably declined in England. But it is certain that in many places such conditions are present as would, if cholera were introduced, assist in the spread of that disease. It is to be hoped that in all these cases the local Sanitary Authorities will at once do everything that can be done to put their districts into a wholesome state. Measures of cleanliness, taken beforehand, are of far more importance for the protection of a district against cholera than removal or disinfection of filth after the disease has actually made its appearance.

Preventive Inoculation.—Admitting the value and effectiveness of the principles above referred to, it is none the less certain that considerable communities are quite unable to command the conditions to be desired, and consequently the question has arisen as to the possibility of protecting the individual members of such communities from the danger of infection by the inoculation of minute doses of the poison which produces cholera. Although the idea of inoculation against cholera is not a new one, the first process established on a scientific basis was that of Haffkine.

Up to 1895, Haffkine always made use of the double injection, the first vaccine being a culture attenuated by aeration, the second being one intensified by passage through guinea-pigs. Owing to difficulties in getting persons to attend for the second inoculation, the present-day practice is to give a single injection of the stronger virus. The general conclusions to be drawn concerning preventive inoculations are as follows:—(1) The protective effect of anti-cholera vaccine commences soon after the operation, and increases rapidly for the first four days and lasts about fourteen months, after which it diminishes rapidly and disappears completely. By using larger doses a more lasting protection would appear to be assured. (2) During the period of its activity, the vaccine reduces the number of cases amongst those protected to less than a tenth of those occurring amongst the uninoculated. (3) The mortality of those who contract the disease, whether inoculated or not inoculated, differs but little, and the course of the disease would appear to be unaffected by the previous inoculation.

DENGUE.

As a specific febrile disease peculiar to warm climates, characterised by severe articular and muscular pains, and often by a cutaneous eruption, our earliest knowledge of dengue does not go farther back than 1780, when it prevailed extensively in Egypt, Batavia, Spain, and Portuguese India. Its first recognition as a distinct disease was made during outbreaks in India in 1824, and subsequently in the West Indies and Southern States of America in 1827–8. Since then it has repeatedly been recognised and described in various tropical and sub-tropical countries, more particularly as endemic in Egypt, East Central Africa, Arabia, some parts of India, the Hawaiian Islands, Bermuda, and Honduras. In the intensity of its epidemic manifestations dengue closely resembles influenza; it spreads mainly by personal contact, adhering closely to lines of traffic, but sporadic

cases are often observed to break out almost simultaneously in several parts over a wide area. As the *incubation* period is very short, extending often only over a few hours, its " simultaneous " appearance needs to be interpreted with discrimination.

Influence of Season, Soil, and Locality.—The relation of the disease to heat is clearly defined. Even in tropical countries epidemics of dengue usually attain their maximum during the hot season, but do not always decline or die out in the coldest months. Rain appears to have only an indirect influence by its relation to temperature.

The physical and geological characters of the soil appear to have no significance in respect to the sporadic or epidemic manifestations of the affection. As a rule, epidemics are limited to towns, especially to the low-lying, filthy, and overcrowded quarters, and the attack may be limited to such, or may involve the whole population. All ages and both sexes seem to be equally attacked; but its fatality is more marked in both the very young and very old. In some epidemics, a distinct tendency to abort has been noticeable among pregnant women attacked with dengue.

Infectivity and Etiology.—There seems to be little room for doubt that dengue is highly infectious, although some authorities question this. From analogy the infection may be assumed to be microbial. Several observers have found what they believe to be parasitic bodies in the blood of patients suffering from the disease, but the specific agent has not been satisfactorily demonstrated. Ashburn and Craig,* as the result of experimental investigations regarding the etiology of this disease, point out that the intravenous inoculation of unfiltered dengue blood into men is followed by a typical attack of the disease. The same result follows the intravenous inoculation of filtered dengue blood, but no organism, either bacterium or protozoon, can be demonstrated in either fresh or stained specimens of dengue blood with the microscope. The cause of the disease is probably ultramicroscopic. Dengue can be transmitted by the mosquito, *Culex fatigans*, and this is apparently the most common method of transmission. The period of incubation in experimental dengue averages three days and fourteen hours. The conclusion may be drawn that dengue is not a contagious disease, but is infectious in the same manner as is yellow fever and malaria.

One attack usually confers a protection against a second infection, but in connection with this aspect of the disease it is believed that if the eruption proper to the second stage of the affection fails to be clearly manifest, the patient is liable to relapses or recurrences. In some epidemics, epizootic disorders among horses and cattle are said to have synchronised with dengue in men. The precise value of this observation has not been made clear, nor has it been determined whether, in these instances, the animals suffered from dengue or not.

The mortality from this affection is small, fatal cases occurring usually only in debilitated persons, or in the very young or old.

* Ashburn and Craig: "The Etiology of Dengue Fever." *The Philippine Journal of Science*, vol. ii., May 1907.

DIARRHŒA.

Although, in the ordinary sense of the term, diarrhœa is simply a physiological process, and merely symptomatic of either the normal reaction of a healthy bowel against irritating contents, or of some morbid internal condition, still considerable evidence exists to show that the diarrhœa which contributes so large a share to the mortality of young children, especially at certain seasons of the year, is of a distinct kind and merely the most prominent manifestation of an epidemic disease belonging to the zymotic group. As affecting large numbers of persons at the same time and place, and displaying a decided affinity for certain populous places during certain seasons, the diarrhœa now to be discussed may be designated as *Epidemic diarrhœa ;* and, in the matter of its epidemiological features, its symptoms and pathology, constitutes a general disease, of which the diarrhœa is but one of its several symptoms.

According to Ballard, " the leading phenomena of the disease are diarrhœa, vomiting, convulsive phenomena ; a bodily temperature at certain periods above, at other periods below, what is normal ; reduction in quantity or actual suppression of urine, embarrassed breathing, and, when looked for, commonly physical indications of pulmonary hyperæmia or inflammation, pallor of surface of the body, loss of bulk and flesh, and exhaustion, with its various well-known clinical features. I must add that occasionally there is jaundice. Now and then a (fugitive) rash has been observed on the body." After giving detailed remarks upon the various symptoms, he goes on to say that " I may here state my strong suspicion, almost my belief, that the malady usually characterised by diarrhœa may run its course from first to last, and even to death, without any remarkable diarrhœa at all. In other cases, although diarrhœa occurs, it is by no means the prominent symptom of the disorder ; it may be comparatively of trifling amount or of short duration."

Influence of Age, Sex, and Season.—This is by far the most fatal of the zymotics in infancy, causing a mortality of about twenty-five per thousand births. The first year of life, especially from the third to the ninth month, has by far the greatest mortality. From infancy the mortality diminishes until about the twentieth year, after which it again increases until the end of life. No age is exempt from attack, but the liability to attack seems to be slightly greater in the second year than the first, or, at all events, is far greater in the first two years than in the third or later years. It is comparatively small in the first three months, and probably increases up to the end of the first or beginning of the second year.

	England and Wales.		London.		Urban Counties.		Rural Counties.	
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
Under 1 year of age .	25·42	21·27	17·57	16·20	30·6	25·2	12·80	11·64
Under 5 years of age .	7·32	6·10	4·55	3·26	9·1	7·4	3·88	2·64

The foregoing table shows the deaths from this group of diseases in the two age periods of under one year of age and under five years of age for every thousand births, during 1905, for certain typical areas. Because of their relation to infantile mortality, exceptional importance attaches to diarrhœal diseases at the present day. At certain seasons and in certain

localities it is this factor that determines whether the mortality among young children shall be high or low. Respecting the incidence of diarrhœal fatality in urban as compared with rural areas, instructive information is afforded by the accompanying table. Thus we learn that children under five years old succumb from diarrhœal diseases in a higher ratio in the urban areas than in the rural. We further learn that more boys of this age die from diarrhœa than girls, both in town and country.

Fatal diarrhœa occurs at all seasons, but increases greatly in summer. Whitelegge has shown that, in London, the mortality curve, based upon the records of many years, indicates a rise throughout June, rapidly increasing in July, and reaching its maximum in the first week of August, after which it falls again rapidly throughout September and October. During the rest of the year there is very little variation. The same facts apply closely for other large towns, where diarrhœa may be regarded as largely endemic. In many of our large towns epidemic diarrhœa causes a heavy annual mortality.

Infectivity and Etiology.—The incubation period is apparently very short, varying from a few hours to a couple of days. In many instances diarrhœa has appeared to be infectious by means of the excreta, and it is probable that this is the main channel by which the infective agent leaves the body. The precise micro-organism upon which infection depends has not been identified with certainty. Klein has described an anaerobic organism, the *B. enteritidis sporogenes*, which he associates with localised diarrhœa epidemics due to milk, with summer diarrhœa, and with so-called English cholera. Our own experiences suggest that there is no causal relation between this microbe and these various disease manifestations.

Morgan's report on the bacteriology of the summer diarrhœa of infants * suggests that the infecting organism is a bacillus belonging to the hog-cholera type. It is a motile rod about the size of the Bacillus enteritidis of Gärtner, it is non-spore-bearing, does not liquefy gelatin, and gives a negative reaction in broths containing mannite, dulcite, lactose, and sucrose but produces acid and a small amount of gas in glucose broth. This micro-organism clearly belongs to the intermediates of the colon-enteric series of bacteria, and is pathogenic for animals, producing diarrhœa and death in young rabbits, rats, and monkeys, when these animals are experimentally fed on cultures. It differs from the bacillus of hog-cholera and other closely allied forms by producing some acidity in milk, in the production of a large amount of indol, and in its failure to produce acid or gas in arabinose, maltose, and dextrin. We, ourselves, have had an extensive acquaintance with this group of micro-organisms, and think it improbable, from a bacteriological standpoint, that a sharp line of demarcation will be found to exist between acute infective diarrhœa and catarrhal diarrhœa in infants or adults. It is not unlikely that the difficulties of clinical diagnosis in such conditions lead to the classification under one name of cases due to different micro-organisms. An analogy to this is seen in the case of enteric fever, under which all cases now designated as paratyphoid were till recently included. The same is the case in regard to the clinical group of cases returned as dysentery. In spite of some gaps in the chain of evidence, we are disposed to regard this bacillus, as isolated and described by Morgan, to be the probable causative agent in the production and dissemination of epidemic diarrhœa.

* Morgan: "Upon the Bacteriology of the Summer Diarrhœa of Infants," *Brit. Med. Journal*, 1907, vol. ii. p. 16.

The chief facts concerning the prevalence of this form of disease may be summarised in the terms of Ballard's * inquiry into its causation.

Loose porous soil is most conducive to mortality from epidemic diarrhœa, particularly if coupled with organic fouling of the earth, no matter whether vegetable or excremental. Diarrhœa is prevalent upon sites such as "made soils," or on ground polluted by drain or cesspool leakage. Both excessive wetness and excessive dryness of soil seem to lessen diarrhœal mortality, but a moderate dampness of soil favours it.

The mortality from diarrhœa is usually high when the air temperature is high, but this is only indirectly so, because the highest mortality coincides less with the highest readings of the air-thermometer than it does with the thermometers in the soil. The summer rise in the diarrhœa death-rate does not commence until the mean temperature of the 4-foot soil-thermometer has reached 56° F.; no matter what heat may have been recorded by the air- and 1-foot soil-thermometers. The maximum mortality and decline in the diarrhœa rate coincide with the mean weekly maximum and decline of the temperature recorded by the 4-foot earth-thermometer.

Rainfall exerts little influence, except by its effects upon soil-temperature. The diarrhœa death-rate is greater in dry seasons and less in wet ones. The diarrhœal prevalence and death-rate are notoriously greatest among the poor, where they are often associated with contributory conditions of want of cleanliness, lack of ventilation and light, together with emanations from earth-closets, drains, sewers, cesspools, and other accumulations of filth. Overcrowding and density of buildings upon an area materially increases the tendency to diarrhœa.

Among other contributory causes are maternal neglect of infants, the occupation of females from home, and the artificial or bottle-feeding of young children. The fouling of milk and other food stored in small, overcrowded and ill-kept tenements probably plays the greatest part in the production and prevalence of diarrhœal diseases among the poor. Upon these and other observations Ballard makes the inference "that the essential cause of epidemic diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism not yet isolated. That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season, and on the presence of dead organic matter, which is its pabulum."

Newsholme's study of epidemic diarrhœa leads to the conclusion that "given two towns equally placed so far as social and sanitary conditions are concerned, their relative diarrhœal mortality is proportional to the height of the temperature and the deficiency of rainfall of each town, particularly the temperature and rainfall of the third quarter of the year." He also agrees with Ogle that diarrhœal mortality becomes high when the mean weekly temperature of the air rises to about 68° F., and considers that diarrhœa is due to surface accumulations of offensive matter in the neighbourhood of houses, rather than to a polluted subsoil.†

A distinction must be made between the epidemic diarrhœa indicated in the foregoing and certain epidemic outbreaks of diarrhœa which occasionally occur in public institutions. These latter can usually, upon investigation, be traced to articles of food or drink, especially water, when containing

* Ballard: "On Epidemic Diarrhœa," Rep. Med. Off. Loc. Gov. Board, 1887; *also* "Report on Middlesbrough Epidemic," *idem*, 1889.

† Newsholme: "A Study of Epidemic Diarrhœa," *Public Health*, December 1899.

excess of mineral salts, sewage, or vegetable matter. Similarly, milk and butter, or cheese, may give rise to diarrhœa, owing either to fermentative changes in themselves or to fouling by some specific germ; especially when stored in cellars or ill-ventilated places. Tinned meats, pork pies, ham and game, or even fish, have on several occasions been traced as the ultimate cause of extensive diarrhœal outbreaks. In these cases the poison partakes of the nature of a chemical body, the product of putrefactive changes in the food, and is altogether unassociated with the seasonal and telluric conditions hitherto considered.

Prevention resolves itself into the avoidance of organic pollution of the soil, the absolute necessity of cleansing and watering streets, the absolute avoidance of "made soils" as sites for dwellings, the exclusion of soil-air from the house, the careful storage of all food, more especially milk, in suitably arranged and well-ventilated larders, and the disinfection of all excretal evacuations.*

DIPHTHERIA.

Under the name of angina maligna, epidemics of this disease have been known since very early times; but as applied to epidemics of malignant sore throat destroying life by suffocation, attacking children rather than adults, and sometimes leaving paralytic sequelæ, the name diphtheria dates only from about 1826. The history of this affection indicates a tendency to cyclical epidemicity, though the cycles "have extended over periods of various length, many of them only a few years, and others lasting several decades." This is particularly well shown in the experience of England, where localised outbreaks occurred from 1815 to 1825, after which the country was almost free from the disease until 1857, when, as part of a general prevalence over the whole of Europe, it appeared again. Since then the disease has practically never been absent from this country, and at the present time shows distinct indications of a tendency to increase in prevalence.

Influence of Climate and Season.—Although no climate can be said to give immunity, the tropics suffer less than cold and temperate climates.

The curves of both seasonal prevalence and mortality show a marked relation to cold, both being greater during the autumn and winter than during the warmer months, the maximum mortality being reached in November and December, and the minimum in the summer. The same general relation of diphtheria prevalence to the seasons of the year appears to hold good as regards other countries. In Great Britain, atmospheric humidity is considered most favourable to the general prevalence of diphtheria, but American experience indicates that it can prevail with severity in very dry weather. Newsholme † believes that "diphtheria only becomes epidemic in years in which the rainfall is deficient, and the epidemics are on the largest scale when three or more years of deficient rainfall immediately follow each other. Occasionally dry years are unassociated with epidemic diphtheria, though usually in these instances there is evidence of some rise in the curve of diphtheritic death-rate. Conversely, diphtheria is nearly always at a very low ebb during years of excessive rainfall, and is only epidemic during such years when the disease in the immediately pre-

* Richards: "The Factors which determine the Local Incidence of Infantile Diarrhœa," *Journal of Hygiene*, vol. iii. p. 325.

† Newsholme: *The Origin and Spread of Pandemic Diphtheria*, London, 1898.

ceding dry years has obtained a firm hold of the community and continues to spread, presumably by personal infection." How far the influence of season upon diphtheria prevalence is direct, by stimulating the activity of the microbial cause of the disease, and how far it is indirect, by increasing individual susceptibility, is uncertain; but probably it acts in both ways. As Longstaff * has insisted, there is little doubt but that anything which tends to damage the mucous lining of the throat, such as ordinary catarrhs, predisposes to attack by diphtheria, and increases the general susceptibility of the body to infection, given the presence of the efficient cause of the disease.

Influence of Locality.—Until the last few years, diphtheria was especially a disease of sparsely populated localities; but now, one of its most striking features is its tendency to prevail in towns, and in the more densely peopled areas. This is particularly noticeable in children under five years of age, who die of it practically twice as fast in the urban areas as they do in the rural. During the period 1861–70, while the diphtheria mortality rate per million living was, for England and Wales, 187, it was for London only 179. In the six years 1900–5, the rates were 199 for England and Wales and 243 for London. Of the registration counties of England and Wales there were, in 1891–1900, eight in which the uncorrected death-rate at all ages from diphtheria exceeded the average, namely, 26 in each 100,000 living. The rate was 50 in London, 46 in Essex, 39 in South Wales, 36 in Kent and in Leicester, 32 in Monmouth, 31 in Middlesex, and 30 in Sussex. The following figures are given by the Registrar-General as to deaths from diphtheria, per million living, of both sexes at varying ages, for the ten years 1891–1900 :—†

	All Ages.	0–	5–	10–	15–	20–	25–	35–	45–	55–	65–	75 and upwards.
England and Wales	263	1362	679	125	36	20	16	14	12	15	12	9
Urban Counties .	297	1653	704	103	28	18	16	12	12	14	12	9
Rural Counties . .	201	829	614	167	52	29	17	20	15	20	15	11

It is more than likely that the present excessive prevalence of this disease, as well as of most other infectious diseases, in the urban areas is caused by the close aggregation of school children which obtains there, as compared with the rural districts.

It has elsewhere been pointed out that soil dampness appears to be associated closely with the prevalence of diphtheria; but admitting the material influence which this condition must have in impairing the general health of communities, and in establishing conditions of negative resistance in individuals against diphtheria, still, in the absence of any definite knowledge that the special virus of diphtheria is a normal inhabitant of the soil, it is difficult to regard the influence of soil states as etiological factors in this disease other than as an indirect one.

Mortality.—The earlier statistics regarding diphtheria were unreliable owing to the disease having been confused with scarlet fever, croup, and laryngitis. In proportion as medical diagnosis has become more exact, the mortality ascribed definitely to diphtheria has risen, while that from

* Longstaff: "The Geographical Distribution of Diphtheria," Rep. Med. Off. Loc. Gov. Board, 1887; *see also* "Studies in Statistics," 1890.

† Supp. to the 65th Annual Report of the Registrar-General in England and Wales, 1907.

croup has fallen. Whatever the reason may be, the statistics for the last thirty years show that there has been a notable increase of diphtheria mortality in England and Wales, an increase affecting children more especially. In this respect, diphtheria contrasts with scarlet fever, from which the mortality has declined within the same period in a remarkable degree. In the present day, the mortality from diphtheria is probably understated, for it is known that of the deaths ascribed to such conditions as "tonsillitis," "quinsy," "ulcerated sore throat," and "membranous laryngitis" a considerable proportion are really diphtheritic.

In comparing the mortality actually due to diphtheria in the recent and in previous decennia, it is noteworthy that when the recorded mortality from diphtheria is combined with that from croup the age incidence of that mortality in the earlier decennia tallies closely with the known incidence of fatal diphtheria to-day. The mortality from diphtheria and croup is lower at the present time than it was forty years ago. The figures for 1891–1900 show a death-rate at all ages among persons of both sexes of 314 per million; among males it was 321 and among females 308.

The following table, quoted by Tatham,* gives, for the administrative County of London, the number and proportion of notified cases of diphtheria in the ten-year period ending 1905, together with the percentage fatality among the attacks at the several ages. It shows that, according to London experience, the incidence of diphtheria is limited mainly to childhood, the ages from two to five being the most liable to attack. Although comparatively few cases occur in the first year of life, the fatality among infants at that age is excessively high. In proportion to population, the notified cases are few after the tenth year of life, and the fatality is below the mean except among women over fifty-five years of age. During 1905, the diphtheria mortality per million living in England and Wales was 160, while for London the corresponding ratio was 111.

Ages.	Cases Notified.		Deaths.		Percentage Fatality.	
	Males.	Females.	Males.	Females.	Males.	Females.
All ages	53,671	63,890	9059	9592	16·9	15·0
Under 1 year	1,477	1,128	630	528	42·7	46·5
1–2	4,044	3,561	1571	1445	38·8	40·6
2–3	5,219	4,777	1537	1488	29·5	31·2
3–4	6,264	6,144	1481	1469	23·6	23·9
4–5	6,180	6,473	1188	1326	19·2	20·5
5–10	16,854	20,328	2110	2692	12·5	13·2
10–15	5,865	7,753	309	341	5·3	4·4
15–20	2,766	3,812	73	81	2·6	2·1
20–25	1,802	3,193	43	39	2·4	1·2
25–35	2,099	4,287	43	77	2·0	1·8
35–45	739	1,587	32	43	4·3	2·7
45–55	235	603	24	23	10·2	3·8
Over 55	127	244	18	40	14·2	16·4

Infectivity and Etiology.—It is now well established that diphtheria is a highly contagious disease, transmissible from person to person, and having a short incubation period ranging from a few hours to five days. The early symptoms are often insidious, but in most cases the membrane is visible within a few days of the onset, if not at first.

* Tatham: Article on "Medical Statistics" in Allbutt and Rolleston's *System of Medicine*, vol. i. p. 61.

In non-fatal cases the disease runs its course usually in two or three weeks.

As regards the actual diffusion of the disease, direct infection from the case plays the chief part. In this process, the virus is, probably, given off by the breath from the throat of the patient, but actual contact, as in kissing, and the attachment of the virus to drinking vessels and spoons is in many cases responsible for infection.

Since Löffler first isolated the *B. diphtheriæ* in 1884, it has been recognised as the essential factor of diphtheria, but experience has shown that its identification is not such a simple matter as it at first promised to be. This arises from the fact that there occur constantly in the throat and elsewhere certain micro-organisms simulating *B. diphtheriæ* in one or more respects, but devoid of the same pathogenic significance. The main characters by which the true diphtheria bacillus can be identified are four in number. First, the macroscopic and microscopic appearance of the growth on serum. Secondly, the behaviour of the suspected organism to stains such as Löffler's methylene blue, Gram's, and especially Neisser's, stain for granules. Thirdly, the acid reaction shown to litmus by a subculture in neutral or slightly alkaline broth, containing 2 per cent. of dextrose, after forty-eight hours at 37° C. Fourthly, the test of pathogenicity on subcutaneous injection into a guinea-pig. In practice, however, it is not always possible to apply all these tests before giving an opinion, especially if a verdict is required within twenty-four hours. Under these circumstances, it is from the microscopical appearance of the growth on serum as small, circular, opaque, whitish discs, and from its dotted or beaded staining reactions, that the conclusion is commonly arrived at that in a given material "a micro-organism is present, morphologically indistinguishable from the bacillus of diphtheria."

A study of the literature shows that, while there is practical unanimity with regard to the character of the typical *B. diphtheriæ*, there is some difference of opinion as to the nature of certain bacilli with which it is liable to be confused. These diphtheroid micro-organisms practically resolve themselves into three groups. Group I. consists of those which fulfil all the requirements of the genuine bacillus of diphtheria, including morphology, staining, acid production, and pathogenicity. The other two groups are non-pathogenic to guinea-pigs. Group II. consists of organisms resembling *B. diphtheriæ* in morphology, staining, and in acid formation, but differing from that organism only in the fact that they are not pathogenic to guinea-pigs. Organisms of this type are generally considered to be attenuated examples of Löffler's bacillus. Group III. is composed of Hoffmann's bacillus, which differs from *B. diphtheriæ* not only in being non-pathogenic for guinea-pigs, but also in morphology, staining, and in producing, not acid, but alkali in dextrose broth. A further group has been described consisting of the so-called *B. xerosis*. This organism occurs in the conjunctival sac both in health and disease, and resembles the diphtheria bacillus in microscopical morphology more closely in some respects than does Hoffmann's bacillus, but differs macroscopically, does not stain with Neisser, does not produce acid in dextrose broth, and is quite devoid of pathogenicity for guinea-pigs. In addition to the foregoing, certain fusiform micro-organisms are met with in swabs from sore throats which are not connected with true diphtheria; these fusiform bacilli are apparently associated with an acute necrotic process of the pharynx and soft palate, occurring under obscure conditions and known as Vincent's angina, which is distinct from diphtheria though, in its clinical manifestations, occasionally

closely resembling it. There should be no difficulty in differentiating these microbial forms from diphtheria bacilli.*

One of the most perplexing problems in connection with diphtheria is the duration of infectivity in the throat. As in the case of some other diseases, there is little doubt but that many persons, who have recovered from an attack of diphtheria, or perhaps merely been in contact with such a case, can harbour the bacilli of diphtheria in their fauces and posterior nares without displaying any outward manifestations of the disease. Such carriers of infection are a fruitful source of infection to others. The difficulty is how to detect and control them. Probably the only remedy is to systematically bacteriologically examine the mucus from the throats and posterior nares of all persons who have been in contact with the diphtheria sick, and so long as any suspicious bacterial forms are detected submit to daily sprayings with chlorine water. In the routine examination of throat swabs, when any doubt exists as to the nature of the micro-organisms found, the inoculation of a guinea-pig should be made, but an indecisive result may be due to the attenuated condition of the bacillus. Numerous cocci are always present in the false membrane of diphtheria; these were formerly looked upon as the cause of the disease. Their presence is, however, probably entirely the result of secondary infection.

It is usually said that diphtheria confers no immunity against subsequent attack; this may be so in respect of man, but undoubtedly some animals, such as the horse, are, if not actually immune against the toxic effects of the products of the diphtheria bacillus, certainly highly refractive. The practical recognition of this fact is, of course, the essence of the well-known procedure of treating the disease by injections of "anti-toxin" obtained from the serum of an immunised animal.

The *period of infectiveness* has been variously stated by different observers as being from fourteen days to eight weeks; this, however, is probably an under-estimate, as Schäfer has reported the persistence of Löffler's bacillus in the tonsillar mucus seven and a half months after recovery from an attack of diphtheria. Moreover, in this connection, Gresswell has observed that in certain individuals diphtheria may, so to speak, "become chronic, and subject from time to time, especially upon exposure to cold and damp, to recrudescence." † It is needless to remark, perhaps, these considerations are of the utmost importance, and, if confirmed, will necessitate material modifications as to our estimate of the period of infectivity in cases of this disease.

Owing to the statements of various authors, it was long a current belief that a chronic infective process, observed in the mucous membrane of the mouth and pharynx of fowls and pigeons, was intimately connected with human diphtheria. This is now known not to be the case, as these necrotic processes are quite different diseases, both as to pathology and micro-organism. Cats, however, unquestionably suffer from a disease which bears a close affinity to human diphtheria. Klein has shown that the cat is the only animal in which, either with diphtheritic membrane or with cultures of the bacillus, it is possible to produce a definite and striking result on the

* Some interesting information on this bacillus and other types will be found in "A Study of the Virulence of the Diphtheria Bacilli," by Graham-Smith, *Journal of Hygiene*, vol. iv. p. 258; *also* in "The Seasonal Prevalence of Hoffmann's Bacillus," by Boycott, *ibid.*, vol. v. p. 223. The reader should also consult "Sur une Forme particulière d'Angine diphtheroide," by H. Vincent, *Archives Internat. de Laryngologie, d'Otologie, et de Rhinologie*, January and February, 1898; *see also* a paper on "Vincent's Angina," by H. W. Bruce, *Lancet*, 1904, vol. ii. p. 135.

† Gresswell: "Diphtheria as a Chronic Malady in Certain Individuals," *Trans. Epidem. Soc. London*, N.S. vol. v. 1885-6.

cornea and conjunctiva or on the fauces and palate. Further, cats suffer naturally from, and, by inoculation with human diphtheritic membrane, can be made to suffer from, a form of broncho-pneumonia which, as evidenced by subsequent paresis and inflammation of the kidney, is evidently a disease equivalent to human diphtheria. Therefore, the cat must be considered as susceptible to human diphtheria, and capable of communicating the disease to other cats and also to human beings.

Klein has further shown that pure cultivations of the bacillus of diphtheria produce by inoculation a severe constitutional disease in cows. A swelling appears at the point of inoculation, increases for a week, and then subsides. Broncho-pneumonia sets in, crops of vesicles appear upon the teats and udders, and the kidneys undergo fatty degeneration. The fluid from the vesicles, and also the milk taken from healthy teats, with every precaution contain the same bacilli. Cats fed upon this milk develop in a few days a severe and often fatal illness apparently identical with that just described as occurring naturally in these animals, and equivalent to human diphtheria. In the cat, as in the cow, the lung seems to be the chief seat of the disease. As Klein says, it need hardly be added that these results lead in great measure to a right understanding of certain epidemics of milk diphtheria, and clearly show that, apart from human infection of the liquid, milk may be a medium of infection from the cow, as in the cases at Camberley and Yorktown, Enfield, Barking and Croydon.*

Water has been suspected of conveying infection, but no complete demonstration has been made that diphtheria is ever transmitted by this agency. In a similar way, air has been credited with being the medium for disseminating this affection, but on very imperfect evidence. It is probable that cases of true wind-convection for any distance are of the utmost rarity. Cobbett † records some striking instances of infection among children in which the vehicular agent for the conveyance of the virus was apparently slate pencils used during lessons.

Thorne-Thorne has called attention to the special incidence of diphtheria on schools, and concludes " that, apart from age and susceptibility, ' school influence ' so-called tends to foster, diffuse, and enhance the potency of diphtheria, and this, in part at least, by the aggregation of children suffering from that ' sore throat ' which commonly is prevalent antecedent to, and concurrently with, true diphtheria." The period of life at which there is most susceptibility to acquire diphtheria is from three to twelve years of age, and school attendance increases the risks of personal infection by the aggregation and prolonged association of children together. So often have outbreaks of true and typical diphtheria, following minor throat illness, occurred in particularly isolated places, and under conditions which exclude the likelihood of their having resulted from any importation of the infection from elsewhere, that an idea has grown that possibly ordinary sore throats may be able to acquire a progressive degree of the property of infectiveness. At present there is no precise knowledge as to the fact of this actually taking place; but it is suggestive of the need to correct any faulty sanitary conditions of schools and other buildings which may in any way tend to ill-health.

Shirley Murphy has shown that when allowance is made for the period of incubation of the disease, there is a marked fall in the number of cases of diphtheria notified for the three or four weeks embracing the summer school holiday, the effect being most marked for cases at ages three to thirteen,

* Klein: Supp. to Med. Off. Loc. Gov. Board 19th Report, 1889, p. 162.
† Cobbett: see *Journal of Hygiene*, vol. i. p. 271.

the years of school attendance. At the same time, school attendance is only a means of spread of diphtheria; it is not the chief cause of the recent increase of diphtheria in England.

The steady enforcement of school attendance has been associated with a declining amount of diphtheria in Berlin and Hamburg in recent years; whereas in Christiania, Stockholm, and Copenhagen, there has been a great increase of diphtheria since 1880, not associated with any increased enforcement of school attendance.

For many years it was thought that accumulations of filth and drainage defects were the direct cause of the origin and spread of diphtheria. In the light of more recently acquired knowledge, there is reason to think that this older belief must be modified, and that the true part which insanitary states play is by way of predisposing to infection by lowering the standard of health rather than by being the actual origin of the disease.

Prevention.—Of the first importance are isolation and disinfection. All insanitary conditions in and around the dwelling should be sought for and remedied. No children from infected households should be allowed to attend school; and if diphtheria is at all prevalent in the district the schools should be closed. Failing this, the children attending should be medically examined daily, and all cases of sore throat segregated and forbidden to attend school until quite recovered. Milk-supplies should be inquired into, and any doubtful ones stopped at once. Milk should in all cases be boiled, especially that given to children. Isolation should be prolonged for about three weeks after disappearance of local symptoms; and bacterial cultivations from the throat secretions systematically made during convalescence, and so long as the bacilli are found isolation should be maintained. All expectoration and throat discharges should be either received into vessels containing a disinfectant, or preferably wiped off with rags which should be burnt. Disinfection of clothing, bedding, furniture, and rooms must be carried out in detail. There are some indications that injections of serum anti-toxin may be both preventive as well as curative. In New York it is the usual course to immunise all members of the family who have been exposed to infection, and Biggs * gives some interesting examples of its use. Netter † reports on the same plan of treatment at the Trousseau hospital. Slawyk ‡ and Kraus § also speak favourably of preventive injection as the result of their experiences in Berlin and Gratz respectively.

Although the evidence is far from conclusive, it affords a fair presumption of the efficacy of anti-toxin as a preventive. Its preventive power is not established under twenty-four hours after injection, and appears to cease at the end of four weeks; in spite of this, we are of opinion that in anti-toxin we possess a means of prevention against immediate diphtheria infection which should not be neglected, and that, where diphtheria is prevalent, children should be injected with from 300 to 500 units of anti-toxin, and that the dose be repeated at the end of three weeks.

* Biggs: *Med. News*, Philadelphia, vol. lxxv. p. 97, 1899.
† Netter: *Presse Medicale*, 1902, p. 387.
‡ Slawyk: *Deutsche Med. Wochenschr.*, 1898, p. 85.
§ Kraus: *Prag Med. Wochenschr.*, 1900, Nos. 19 and 20.

DYSENTERY.

Formerly this disease was very prevalent in this country, but in the present day it is practically confined to hot climates. Clinically, it may be described as an affection marked by frequent, bloody, mucous, serous or ichorous stools, accompanied with tormina and tenesmus, and often with some febrile disturbance. Pathologically, it may be regarded as a specific inflammation of the inner coats of the large intestine, having a tendency to terminate in ulceration, suppuration, or even gangrene of the affected tissues. The disease may be either acute or chronic, sporadic, endemic, or epidemic in its manifestations.

Influence of Climate, Season, and Locality.—Dysentery being an ubiquitous disease, we find it prevailing at one time or another in all climates, but a close examination of its present-day distribution indicates its increased frequency, as an endemic disease, as we approach the equator. Accurate statistical facts in this connection are, however, difficult to obtain, as we have no data for satisfactorily determining the mortality which it causes as distinguished from other "bowel complaints" among the native populations.

Dysentery in all its forms is undoubtedly a seasonal disease. In Europe, as an endemic malady, dysentery has always attained its maximum in summer and early autumn. In the United States, summer is also the season when it is most prevalent. Within the tropics, dysentery is usually most fatal in the third and fourth quarters, when the temperature has begun to fall and the season to become dry. In India, as a whole, dysentery is a disease of the colder seasons ; and among both Europeans and natives is most fatal in late autumn or early winter. While a high temperature is essential to the development of dysentery, as evidenced by its being a disease of warm seasons in Europe, its prevalence, in tropical countries, is only markedly manifest after the temperature has begun to fall, or even when it has reached its minimum. Few facts in connection with the possible relation between dysentery and climate or season are more clear than those which indicate the influence of vicissitudes of temperature and exposure to cold in determining attacks. The whole medical history of both our own and other armies, either in the pre-sanitary or present age, bristles with instances illustrative of the importance of these agencies in the predisposition to this affection, but, in the light of our modern knowledge, we are not disposed to attach to these factors any other value than that they contribute to the general lessening of natural resistibility to infection.

While perhaps it cannot be maintained that the physical condition of the soil is altogether immaterial in respect to endemic dysentery, there is little evidence to show that the geological constitution of the soil has any appreciable influence on the causation of this disease. On the other hand, soil contaminated with excremental matters is undoubtedly one of the most important contributing conditions essential to the occurrence of dysentery. Many of the notable outbreaks in institutions, such as prisons, asylums, and schools are well-known instances of this kind ; so also the terrible outbreaks of the disease in the armies of earlier times were attributable to the pollution of the localities on which large bodies of men and animals remained encamped for many months, resulting in the fouling of both soil and water. The same is true of the present day ; if the ordinary rules of hygiene are violated, the inevitable penalty must be paid in the form of dysentery, diarrhœa, and the prevalence of diseases of this type.

Influence of Diet.—Faulty dietary, especially coarseness of food, the prolonged and exclusive use of salt meat, indulgence in either alcohol or unripe or over-ripe fruits, are all indirect causes of dysentery by predisposing the system to infection. Of still greater importance is deficient nourishment, especially when manifested in the appearance of scurvy. The scorbutic condition modifies in a marked way the symptoms and course of dysentery, being, in fact, one of the most terrible phases of the malady.

The instances in which outbreaks of dysentery have been traced to the use of foul water, particularly water polluted with fæcal impurities, are very numerous. In fact, in the greater number of cases, the various contributing factors to the prevalence of dysentery are quite secondary to the influence of impure water. Of course, in some instances the water merely serves as a vehicle by means of which the specific cause of dysentery is introduced into the system ; in others, it may act only as a predisposing cause of the infection, by virtue of an irritative action on the bowel.

Influence of Malaria and Personal Conditions.—All cachectic states of the constitution powerfully predispose to dysentery ; and malaria is no exception to the rule. In fact, our military experiences show only too well the severity of dysentery incidence among bodies of men who have been reduced by repeated attacks of malaria, subjected to fatigue, and exposed to the sun by day and to chills by night.

Personal conditions, such as age, sex, race, and length of residence in the tropics, appear to be without material influence in the causation of dysentery. It is true, coloured races suffer more than the white, but this is largely dependent on their coarse food, the impure water they often drink, and their more frequent exposure to wet, cold, and other unfavourable conditions. It is rare to find dysentery in towns ; it is specially a disease of rural districts and small villages.

Infectivity and Etiology.—At this period in the history of medicine it scarcely needs to be argued that dysentery is a specific disease and dependent upon a specific poison. The etiology of dysentery, however, is by no means a simple question, as there can be no doubt that what is called dysentery clinically is not in etiological respects one single disease, since some dysenteries are caused by one form of organism and others by another ; in this sense, we recognise that dysentery exists or occurs in two main types, namely, endemic and epidemic. The former type is apparently limited to certain localities, notably the Nile basin, Bengal, various parts of India, Burmah, China, and South Africa ; it runs a chronic course, and is essentially different to the acute outbreaks of dysentery spoken of as epidemic and occurring in armies, camps, and other centres of overcrowding or life under primitive and insanitary conditions. The causative agent of endemic dysentery is a protozoon, known as the *Amœba dysenteriæ* ; while epidemic dysentery is caused by a bacillus, known as the *B. dysenteriæ*. This recognition of the essential difference between the causative agents of these two kinds or types of dysentery suggests the abandonment of such terms as endemic and epidemic, and replacing them by more definite names of *amœbic* and *bacillary* dysentery.

The amœbæ found in the intestinal discharges from cases of amœbic dysentery are rounded or irregular protoplasmic masses usually 25 to 35 μ in diameter, consisting of a central granular protoplasm and an outer hyaline layer or ectoplasm. They often show vacuoles, and may contain red corpuscles and bacteria ; there is a single nucleus about 6 to 8 μ in diameter. The organism may show sluggish movements, blunt processes consisting of ectoplasm being protruded. When injected per rectum into animals they

produce pathogenic effects. These amœbæ have been found in large numbers of cases of tropical dysentery by numerous observers, and their causative relationship to certain types of the disease is beyond dispute; they have also been detected in the pus from abscesses in the liver, following attacks of amœbic dysentery. The precise life-history of this protozoon is not known, but the weight of evidence is in favour of the view that the chief source of infection is by means of dirty water. The *Amœba dysenteriæ* leaves man by the intestinal canal.

In the bacillary form of dysentery, the infective agent is a bacillus, originally isolated by Shiga from the dejecta of cases in Japan. The general cultural characters of this micro-organism are now well known, and its intimate association with explosive outbreaks of acute dysentery have been demonstrated in nearly every country and climate.* In many of its features the *B. dysenteriæ* resembles closely the organism of enteric fever, but is quite distinct from that microbe (*see* page 114). The mode of infection is probably the same as in enterica, that is, sometimes water is the vehicle, sometimes food, in a few cases possibly dust and flies may be the means, while in many instances man owes his infection to direct passage of the germ from the sick to the healthy.

Both in respect of the biological characters of the infecting agents and the epidemic incidence of the two diseases, there is much to suggest a closer relationship between enteric fever and bacillary dysentery than the experimental facts justify us to affirm. Similarly, many are disposed to think that there may be a possible acquired infection capable of development from simple colitis just as there is the probable occurrence of a progressive development of the property of infectiveness in simple "sore throat" up to a condition of diphtheria. The gradually developed infection of bacillary dysentery engrafted on diarrhœa is nowhere better seen than in the experience of military campaigns. Although bacillary dysentery is a disease *per se*, still on service the causes predisposing to the ordinary forms of simple diarrhœa will, if persistent, also predispose to the true spreading epidemic of dysentery. The infectivity of bacillary dysentery lies in the stools; and the doctrine that the dejecta of apparently simple diarrhœa cases can assume an infective character, especially when many patients are accumulated together in camps or barracks, should never be lost sight of. In this connection, the frequent epidemic prevalence of dysentery in asylums is worthy of notice; this is invariably of the bacillary variety and, occurring as it does not only in old but also in new asylums, where no hygienic defects can be pointed to other than some degree of overcrowding, it is suggestive of the existence in the insane of some condition or conditions rendering them peculiarly susceptible to this disease. The problem has been divested largely of theoretical considerations by Knobel,† who adduces evidence in support of the view that dysentery in the insane is not spread by the transfer of recovered cases from ward to ward, but is caused by a normal inhabitant of the colon which becomes pathogenic when the resisting power of the tissue is sufficiently reduced. Our own experiments ‡ with the *B. dysenteriæ* on rabbits are not inconsistent with this view; on the contrary, they are suggestive of the action of the normal intestinal bacteria on the mucous lining of the large bowel after damage by a toxin, introduced into and

* Firth: "An Experimental Inquiry concerning Epidemic or Bacillary Dysentery." *Trans. Patholog. Soc. Lond.*, 1904, vol. lv. Part III., p. 340; also *Journ. Roy. Army Med. Corps*, 1903, vol. i. p. 436. Both these articles give references to an extensive literature on this subject.

† Knobel: "On the Etiology of Asylum Dysentery." *Journal of Mental Science*, April 1906.

‡ Firth: *op. cit.*

circulating in the blood, having an elective affinity for the colon and certain centres in the lumbar or lower dorsal cord. The analogy between the physical states of many insanes in institutions and the cachectic states of soldiers and others exposed to hardships is close, and far from inconsistent with the view that if an impairment of trophic function can reduce vitality and general power of resistance to infection in one set of individuals it can do so in another. We admit the whole question is full of difficulties, and that much has yet to be learnt concerning the etiology of bacillary dysentery ; but all the epidemiological facts are not explicable by stereotyped views concerning the origin and diffusion of specific bacteria, hence we would urge an attitude of reserve and open-mindedness. It is highly probable that the specific cause of bacillary dysentery is often in the human body without giving rise to the disease. The explanation being that the healthy bowel does not afford a favourable soil for its growth ; it is only when the intestinal mucous membrane is impaired, as by excessive or extreme vicissitudes of temperature, by exposure to cold, bad or deficient food, impure water, or by cachectic conditions such as scurvy or malaria, that it becomes vulnerable to the attacks of the lower organisms. The etiological importance of these diverse factors is limited entirely to their influence in disturbing the nutrition of the large intestine.

Prevention.—This will necessarily be based upon the etiology of the two conditions commonly referred to as dysentery. In the case of amœbic dysentery, we believe the surest line of defence will be the protection of water-supplies and the ingestion of clean food and drink, coupled with a high standard of personal cleanliness. We do not wish to imply that, as against this particular form of the disease, no attention need be paid to other conditions contributory to a lessened state of general well-being, but everything points to their playing a much smaller part in favouring this form of infection than they do in bacillary dysentery. In this latter type of the disease we have to remember that the infection is acute and probably highly virulent, passing readily from man to man, and from man to water, food, clothing, and other articles of daily use. Under these circumstances free ventilation, cubic space, the prompt and thorough disinfection of the stools, bed-pans, commodes and enema tubes, are matters of the first importance. In camps, prophylaxis demands that the contents of latrines be disinfected and buried deeply, well away from human habitations ; or, better still, that they be burnt. All drinking water should be protected from contamination, and when open to the slightest suspicion should be boiled. Further, recognising how great a part they play in preparing the body for infection, exposures to extremes of heat and cold, dampness, or to deficient and imperfect diet, must be carefully guarded against, whether for individuals or bodies of men. Finally, recognising a possible etiological connection between simple forms of diarrhœa and bacillary dysentery, especially in camps and other primitive modes of life, care should be taken to disinfect and carefully dispose of all dejecta from even the mildest type of intestinal irritation.

ENTERIC FEVER.

This disease is clearly traceable in the earlier records of medicine, but it was not until 1850 that Jenner was able to demonstrate its differentiation from typhus fever. Enteric fever is distinctly influenced by season, by far the greater number of cases in Europe and America occurring in the late summer and autumn ; the least number of cases occur in April or May. Seasonal prevalence is equally well marked in the tropics. Hirsch has aptly called enteric fever the ubiquitous disease, for it is of practically world-wide distribution ; for many years it was deemed to be less common in tropical than in temperate climates, but making allowance for the fact that certain forms of malarial fever have been frequently mistaken for enteric fever, it is probable that the idea was erroneous. It is beyond dispute that remittent fever in the tropics frequently simulates enteric fever in a remarkable degree, though the autopsy shows the characteristic lesion of the latter disease to be absent. Many cases of the so-called typho-malarial fever are doubtless of the same kind.

Weather has no clear relation to enteric prevalence, except in so far that meteorological conditions may act by modifying the moisture and temperature of the soil, and that rain may either increase or diminish the chances of an outbreak according to the previous condition of the ground.

Ages.	Notified Cases.		Deaths.		Case rate per 1000 living.		Percentage Fatality.	
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
All ages	18,756	15,115	3540	2534	0·9	0·7	18·9	16·8
Under 1 year	24	23	10	11	0·0	0·0	41·7	47·8
From 1 to 2 years	91	65	13	13	0·2	0·1	14·3	20·0
2–3	177	138	23	23	0·4	0·3	13·0	16·7
3–4	270	262	34	23	0·6	0·6	12·6	8·8
4–5	339	296	28	33	0·8	0·7	8·3	11·1
5–10	2,231	1,989	165	172	1·1	0·9	7·4	8·6
10–15	3,011	2,327	254	248	1·5	1·1	8·5	10·7
15–20	2,971	2,216	485	360	1·5	1·0	16·3	16·2
20–25	2,729	2,201	624	370	1·2	0·8	22·9	16·8
25–35	4,003	3,180	1033	638	1·1	0·7	25·8	20·1
35–45	1,837	1,491	498	357	0·6	0·5	27·1	23·9
45–55	737	643	229	175	0·4	0·3	31·1	27·2
Over 55	336	284	144	111	0·2	0·1	42·9	39·1

Influence of Race, Sex, and Age.—Although negroes and other native races are apparently less liable to suffer in their native countries than non-acclimatised persons, there is no evidence to show that *race* of itself exercises any influence over liability to attack by this disease. Very much the same conclusion may be drawn in regard to *sex* at all ages, though, if anything, males are apparently rather more susceptible than females. According to the figures furnished by the Registrar-General, the sex incidence of fatal enteric fever has altered considerably in the course of the last thirty years. In 1871–80, both sexes fell victims in nearly equal proportions, in the succeeding decennium the male rate exceeded the female, whilst in the last ten years the female rate was not more than three-fourths of the male. Up to the age of fifteen the decrease in fatality has been about equal in both sexes, but from that age up to the forty-fifth year the fall has been much greater among females. The foregoing table gives,

for the administrative County of London, the number and proportion of notified cases of enteric fever in the last ten years, in each thousand of population, for each sex at several ages. It shows that the period of life intervening between the tenth and thirty-fifth years is exceptionally liable to attack by enteric fever, the cases at those ages being most frequent among boys. The same appears to hold good for the whole country.

The *seasonal* incidence of enteric fever is shown by the following table, which is based on 46,125 cases notified in London in the fourteen years ended with 1903 (Tatham). It shows that October and November are the months of greatest prevalence, whilst April and May are the months of least prevalence.

	Daily Average.		Daily Average.		Daily Average.
January	8·1	May	5·2	September	13·1
February	6·6	June	6·3	October	15·8
March	5·5	July	7·0	November	15·7
April	4·8	August	8·7	December	11·5

Influence of Place.—European experience indicates that enteric fever is often more prevalent in towns than in the country, and often fixes persistently upon one district. As a rule, in such districts where the disease is endemic, it will be found that insanitary conditions abound, notably impure water-supply, defective methods and arrangements for disposal of excreta, combined with want of care for preventive measures. In these areas, newcomers are especially liable to attack.

In connection with the endemic or epidemic prevalence of enteric fever, considerable importance has been attached to the *rôle* which pollution of the earth by excrementitious matter and movements of the ground water play. Pettenkofer and Buhl traced a connection, at Munich, between the occurrence of enteric fever sickness and mortality and variations in level of the subsoil water which have been confirmed by further observations in Berlin, various parts of Germany, and elsewhere. In the places where the relation has been observed, the soil is porous, the ground water high, and leaking cesspools not only numerous, but in close proximity to wells and other sources of water-supply. Given these conditions, there is no difficulty in appreciating how the purity of water in wells may be affected by changes in the level of the ground water ; and, further, bearing in mind the readiness with which enteric fever is spread by means of specifically polluted water, the true value of the above-mentioned observations as to a causal relation between the prevalence of the disease and the range of fluctuation of the subsoil water are manifest.

Mortality.—The following table, from the Registrar-General's returns, will give some idea of the remarkable diminution in the number of deaths from enteric fever in England and Wales during the last twenty years :—

Year.	Death-rate per 1,000,000.	Year.	Death-rate per 1,000,000.	Year.	Death-rate per 1,000,000.	Year.	Death-rate per 1,000,000.
1886	184	1891	168	1896	166	1901	155
1887	185	1892	137	1897	156	1902	126
1888	172	1893	229	1898	181	1903	100
1889	176	1894	159	1899	198	1904	93
1890	179	1895	175	1900	173	1905	89

The case mortality from this disease varies from 12 to 16 per cent.

Incubation and Protection.—The latent period of enteric fever is liable to considerable variation. The most usual duration is about twelve to fourteen days, but it may range from a few days to thirty ; it seems to be shorter when the poison is introduced by water, or by milk. The peculiarly insidious mode of onset renders any exact determination difficult. The actual illness commonly lasts three or four weeks, but is often protracted by relapses. How far the disease confers protection against a second attack is still doubtful, but the weight of opinion is undoubtedly in favour of the view that it does confer immunity, possibly for life.

Etiology and Infectivity.—The remarkable ability of enteric fever to disseminate itself by means of water, milk, and other media, indicates the virus to be a living organism. Eberth first showed that in many cases of enteric there occur in the swollen mesenteric glands peculiar bacilli rounded at their ends, motile, and occasionally including within a pale sheath one or more spore-like granules. Gaffky and numerous observers have confirmed these statements, and these bacilli are now considered to be the microbial cause of enteric fever.

Rodet, Roux, and others have put forward the view that this bacillus, known as the Eberth-Gaffky bacillus of enteric fever, now admitted to be almost constantly present in the alimentary canal, in the mesenteric glands, and in the spleen of cases of this disease, is no other than the *Bacillus coli communis*, which is a constant and normal inhabitant of the bowels of man and animals under perfectly healthy conditions ; and, further, they have contended that the *B. coli* passed with the normal dejecta is capable of acquiring in sewage specific and virulent properties, so that when re-introduced by water, milk, or other articles of food into a normal individual, it has become endowed with the power of setting up in him the specific and communicable disease—enteric fever. In this view enteric fever may—in so far as it is referred, not to a microbe directly derived from antecedent enteric fever or other disease, but to a saprophyte that has become altered in its physiological effect by sojourn for awhile in sewage—arise, so to speak, *de novo.* To our mind, such a view is untenable, as the two micro-organisms are quite distinct, and all direct experiment shows that the two microbes, while sojourning in sewage, maintain their biological characters unaltered. While holding this view, our duty of preventing pollution with sewage of drinking water, milk, &c., is not less incumbent. For although we maintain that, without the enteric germ, the *Bacillus coli* and other intestinal bacteria are not capable of causing enteric fever, the presence of any of these well-known normal inhabitants of the intestine in water indicates, nevertheless, a probable pollution with excremental matters and possibly with it specific—that is, enteric—material.

It must be admitted that the question is full of difficulty ; but, in the present state of our knowledge, no other opinion is warranted by the experimental facts. It is possible that not only the common bacillus of the colon, but also some other kinds of bacteria, may play an adjuvant part in causing infection by the *B. typhosus*. Sanarelli's work, in particular, is highly suggestive that this is the case,* but as yet we are unable to appreciate fully the value of these results. The problem is rendered no simpler by the circumstance that there exists a variety or type of bacillus which culturally occupies a place intermediate between the true enteric bacillus of Eberth and the common colon bacillus of Escherich. Some of these intermediate forms cause a fever in man closely resembling enterica, and are conveniently referred to as paratyphoid bacilli. The most prominent member of this

* Sanarelli : *Annales de l'Institut Pasteur,* Paris, 1892-4.

group is the *B. enteritidis* of Gärtner, which gives rise to grave symptoms, and is associated with meat obtained from cattle dying of a form of intestinal inflammation. The study of this and similar bacilli, and their relationship with the enteric bacillus, by Nocard, Durham,* and others, has greatly enlarged our views on the subject of enteric infection. Smallman's work † on this subject is full of suggestiveness. He treated some two hundred guinea-pigs with living and dead enteric bacilli, injecting pure cultures into the peritoneal cavities; all died at varying periods following the injection. The micro-organisms cultivated from these animals after death were in the majority of cases true and typical enteric bacilli; but in twenty-two cases in which living enteric bacilli had been injected the micro-organisms found were of the paratyphoid type. It is an interesting question, Whence did they come? They were not found in the fæces of the control animals, but were present in the intestinal contents of the guinea-pigs which had been inoculated with enteric germs; so clear are the facts that it would seem possible that a transformation had been effected within the animal. This conception opens up a wide range of possibilities, not the least important being whether the paratyphoid bacillus in the lower animals is the analogue of Eberth's bacillus of enterica in man, and whether the latter may not be transformed into the former by passage through certain animals, notably pigs, rats, dogs, and cats, and so cause this infection in man. Many of the types of the so-called swine-fever in pigs are suggestive of this sequence of events, while many rats found in styes and yards frequented by infected swine are not free from similar lesions.

In the actual dissemination of the disease, water has been repeatedly proved to play the most important part. Not only in this country, but abroad, various epidemics and groups of cases have been investigated, where a contamination of drinking water by sewage from drains or old cesspools, and, by inference, with enteric excreta, has been proved to be connected with the outbreak and spread of the disease. Complete and instructive evidences as to contamination of drinking water by enteric stools, and wholesale infection by such water, are afforded by the Caterham epidemic in 1887, the Middlesbrough and Tees Valley outbreak of 1890–1, the Worthing epidemic of 1891–2, the Lincoln outbreak of 1905, and many others to be found in the various supplements to the Reports of the Medical Officer to the Local Government Board.

Schüder ‡ has analysed the records of 658 enteric outbreaks occurring during the last thirty years, and finds that 70·8 per cent. were traceable to water pollution. The ability of the specific bacillus to survive for some weeks in water is well known, particularly if sedimented or incorporated in a mass of protecting material; a case recorded by Tavel,§ in which the bacillus had survived in the blind end of a water-main for six months, is particularly interesting.

Milk is another possible source of infection. Schüder shows that, in the period he examined, quite 17 per cent. of the cases had been ascribed to milk. The contamination of the milk may arise from impurity in the water used for washing out the cans, or diluting the milk, or may come more directly from the handling of the vessels and teats by infected persons. In tropical countries, where water buffaloes are a common source of milk-supply, these

* Durham: *Lancet*, 1898, vol. i. p. 154; also *Trans. Path. Soc.*, vol. l. p. 262; also *Brit. Med. Journal*, 1898, vol. ii. p. 600.

† Smallman: *Journ. Roy. Army Med. Corps*, vol. v. p. 137.

‡ *Zeitsch. f. Hygiene*, 1901, vol. xxxviii. p. 343.

§ Tavel: *Centralblt. f. Bakt. u. Parasitkde.*, 1903, p. 364.

animals are often driven straight out of some filthy pond or stream to be milked. If so, the pollution of the milk presents no difficulty.

Other forms of food are probably responsible for about 4 per cent. of cases; the chief sources from which infection may arise are oysters, shell-fish generally, and green foods which are eaten in an uncooked state, such as watercress. Notable instances of infection through all these channels have occurred within recent years.

Although it is true that, in the greater number of epidemics of enteric fever, the cases are due to specifically contaminated water or milk, it is not safe to say that the disease is never conveyed by direct infection, nor must we overlook other possible modes of the spread of this disease. In India and other countries where dry systems of conservancy are in force a possible danger exists in the dislodgment of dried and imperfectly buried excreta from the soil, and their diffusion, as dust, by winds. To this agency we must add the effects of flies which settle and breed upon surface-buried excreta, and then convey the fæcal material and its essential bacteria back to the food of man. If specifically infective, even in the absence of direct experimental evidence, few persons, who have knowledge of the circumstances of life of tropical countries, will be disposed to deny that such dried excretal matter possesses considerable potentialities for evil. Some are of opinion that the *B. typhosus* is essentially a micro-organism of the soil, and capable of leading an independent life, and of reproducing itself in the earth.

From time to time, a good deal of evidence has been forthcoming in favour of the view that the air and gases of sewers or drains which have become specifically contaminated may, if allowed to find their way into dwellings through defective house connections, cause enteric fever among the inhabitants of such dwellings. In the light of recent researches, which indicate that sewage is unable to give off micro-organisms to the air in contact with it, we find it difficult to accept this view as to the occasional origin of enteric fever cases, and are compelled to conclude that some more exact causation has been overlooked in those instances.

Recently, the experiences of the Americans in their volunteer camps of 1898 * and the work of Koch,† and the other members of the Treves Commission have drawn attention to the influence of direct infection from one patient to another as the chief means of maintaining both the endemic and epidemic prevalence of this disease. Both sets of circumstances emphasise the fact that enteric infection may, in fact does, exist in a latent form amongst children and adults, and that the number of notified or recognised cases is no measure of the amount of enterica among the members of a given community. According to Klinger ‡ the healthy, or at least non-specifically sick, can harbour enteric bacilli and excrete them to the common danger. These bacilli-carriers may be of either sex and of any age between eighteen months and sixty years; they have no specific symptoms of typhoid, and are apparently in perfect health. These typhoid bacilli-carriers are of two classes (1) acute carriers who have never before or after the demonstration of the bacillus in their fæces or urine shown any symptoms of sickness, have been in direct contact with the sick and, as in the case of the majority of sick after recovery from the disease, excrete the bacillus for a short time

* Report on Origin and Spread of Typhoid Fever in U.S. Mil. Camps during the Spanish War of 1898, Washington, 1900; *see also* paper on the same by C. Childs, *Trans. Epidem. Soc.* vol. xxv., N.S., 1905 6, p. 173.

† Koch: *Die Bekampfung der Typhus*, Berlin, 1903.

‡ Klinger: *Arbeiten aus dem Kaiserl. Gesundheitsamten*, Bd. 24, Hft. 1, 1906, p. 91; *see also* a paper by Kayser in the same, p. 176.

only and in small numbers, being thus, in comparison with the second class, of little significance; (2) chronic carriers who have, a short or long time before, gone through a regular attack of enterica, and may excrete for months pure cultures of enteric bacilli. Of twenty-three carriers, detected by Klinger from among 1700 persons examined during a period of two years, eleven belonged to the first class and twelve to the second. Further, 482 cases of enteric fever were kept under bacteriological observation during recovery, with the result that 13 per cent. were found to excrete the bacillus during convalescence, but only 1·7 per cent. for longer periods than six weeks after the disappearance of the fever; and of three chronic carriers one was still excreting the bacillus a year after the attack of enteric, and the others excreted specific bacilli for periods varying from eleven to three months. Although Klinger found that only 1·7 per cent. of enteric fever patients may become chronic carriers of the bacilli, Lentz says the proportion may be as high as 4 per cent.

Speaking from our own observations and experiences, we are impressed with the fact that enteric fever bacilli, under certain not fully understood conditions, can live a saprophytic existence in the gall-bladder of a person who has recovered from an attack. Theoretically, as with diphtheria, cholera, and cerebro-spinal meningitis, enteric bacilli from these carriers may infect other individuals and cause enterica, but experimentally this cannot be proved on man; the epidemiological facts, however, although affording no absolute proof, are yet fairly convincing. The most unfortunate feature in the case is that, in the present state of our knowledge, we are unable to free these carriers from bacilli, even when detected; moreover, there is the practical difficulty of getting such unconscious carriers of infection as are detected to remain under surveillance and bacteriological control, or to carry out continuous and efficient disinfectant measures in order to prevent infection being conveyed to others. Finally, before leaving this aspect of the subject, attention may be drawn to the possibility that the existence of enteric-infected houses or places may be largely, if not entirely, due to the presence in them of the carrier, rather than on the presence in dust or crevices of enteric bacilli, and consequently, that in such houses a systematic examination of fæces and urine is of the first importance. In connection with the apparent natural immunity of acute enteric-carriers reference may be made to an article by Wassermann and Citron * on the local immunity of tissues and the place of origin of enteric-immune bodies. These authors maintain that a local immunity of tissues may exist spontaneously as well as after having undergone an attack of enteric fever, the bacillus in such individuals living in the intestine without producing any symptoms, and without causing any increase of agglutinating bodies in the blood.

The experiences of the Americans in their military camps indicated that 98 per cent. of the regiments developed cases of the disease within six weeks after their arrival at the national encampments; nearly half of the enteric fever cases were either missed by the medical officers or wrongly diagnosed. Infected water was not an important factor in the spread of the disease, but out of 1608 cases studied, 62·3 per cent. were "connectable attacks," that is, connectable by infection within the tent or from an adjoining tent. Our own experiences in camp and in hospitals is quite in accordance with this view of the potency of direct infection; in the hospitals, enteric fever amongst the staff is confined almost entirely to those who are working in the enteric wards, and occurs chiefly amongst nurses and

* Wassermann and Citron: *Zeitschr. f. Hygiene*, 1905, Bd. 50, p. 331.

orderlies.* Formerly, the risks attaching to personal service on, and to close association with, the enteric sick was under-estimated, with the result that, in many hospitals, enteric fever patients were treated in general wards side by side with other cases; there can be little doubt this practice is unsound, as the possibilities of the passage of direct infection are very great, especially among the young and exceptionally susceptible.

Prevention.—General measures will be to secure pure air, pure water, pure milk, and to maintain all drains and sewers in good order. If any suspicion attach to either water or milk it should be boiled. To guard against the spread of the disease from the sick to the healthy, all stools and urine should be received into a vessel containing some strong disinfectant, and at once covered up. After this, the excreta may be at once passed into a drain, or buried deeply in the earth, but this must not be done until the stool has been exposed to the action of a strong disinfectant for at least five minutes. If possible, all excreta should be burned. All soiled linen should be at once placed in a vessel containing carbolic acid solution 1 in 20, until they can be removed for proper disinfection by either boiling or exposure to moist heat in a disinfecting chamber. Isolation of the sick person is necessary, and patients ill with enteric fever should not be aggregated together in general wards. Too great stress cannot be laid on the need of the most scrupulous cleanliness on the part of nurses and others attending on the sick, while all clothing and bedding soiled by the patients must be at once transferred to some disinfecting solution before going to the laundry.

These efforts are all well and good once we have the patient under treatment, but the surest and safest way to control, if not actually prevent, the dissemination of enteric fever lies in the observance of these essentials. They are :—(1) detection of mild as well as severe cases, (2) isolation or segregation of the sick, (3) notification, and (4) thorough disinfection. The initiation of a campaign of "stamping out," organised on these lines, has already borne good fruit in more than one of our military garrisons, and there can be little doubt that, as we are able further to develop it, the results will be still better. Probably the early detection of cases, particularly the mild or ambulant forms of enteric constitutes the most important and difficult detail to carry out; while the next in value is the isolation of the sick and those who have been in intimate association with the case or cases. The danger of enteric infection is that the individual, although appearing well, may harbour the bacilli and so infect others. Another point of importance to remember is, that only by repeated bacteriological examination of the fæces and urine are we in a position to say when a person is no longer a source of danger to his neighbours; and further, only by this examination can the latent foci of the disease be discerned. It will be conceded that few public health services can maintain this standard of work; none the less it should be our ideal, for it is only the accumulation of scientific facts that enables us to correct intelligently real hygienic faults.

Inoculation, as a preventive procedure against enteric infection, cannot be said to be employed outside the army. Originally introduced by Wright and Semple in 1896, it is still somewhat in the tentative stage. At the present time, the vaccine material is prepared by growing a virulent culture of the bacillus typhosus in broth for forty-eight hours. This broth culture is sterilised in a water bath by an exposure to 53° C. for one hour. When

* Davies: "The Direct Transmission of Enteric Fever," *Journ. Roy. Army Med. Corps*, vol. iv, pp. 587 and 693.

cool, samples are drawn for testing and, after proof of sterility by aerobic and anaerobic cultures, 0·5 per cent. of lysol is added, and the vaccine bottled in sterile vessels. The vaccine is then standardised by a combination of a germ-enumeration method and the estimation of the weight of the dried bacterial bodies in a measured quantity of the vaccine. The dosage of the vaccine has been fixed at the following quantity :—0·6 of a cubic centimetre of the vaccine, containing 500,000,000 of the bacteria is employed for the first inoculation, and double this quantity is injected ten days later for the second dose. Two injections of these amounts have been ascertained to give the maximum quantity of protective substances with the minimum severity of reaction.

The blood changes following inoculations with vaccines of this nature have been worked out by Leishman,* Harrison,† Smallman and Ward ; ‡ these show that even with very small doses of vaccine a remarkable development of protective substances occurs in the blood of the inoculated. How long they remain in the blood is still open to dispute, but the evidence obtainable is suggestive that the period of protection following a double inoculation is about two years. The protection is far from absolute, and much further work has to be done before we can draw definite conclusions as to the persistence of the protective substances in the blood of the inoculated, and as to the probable measure of protection afforded. Meanwhile, the figures relating to the inoculations which have been done are encouraging, but as submission to the act of inoculation is quite voluntary the number of soldiers so treated is comparatively small. The following facts are given by Luxmoore in regard to the effects of inoculation among men of the 17th Lancers.§ This regiment left England in 1905 for India, and within a few weeks after its arrival enteric fever broke out in it. The results obtained by anti-enteric inoculation can be held to constitute a test-case, as they were checked by examinations of the blood and by necropsies. Of 514 persons in the regiment, 127 submitted to a complete inoculation against enteric by means of two injections, 23 received only one injection, and 364 refused to be inoculated at all. No cases of enteric fever occurred amongst the 127 fully inoculated, 2 cases occurred among the 23 partially protected, and 61 cases occurred among those who refused to be inoculated. It would be difficult to find a more striking series of figures.

The results of similar inoculations among German troops in South-West Africa show a death-rate of 4 per cent. from enterica among the inoculated as against 11 per cent. among the uninoculated.‖ All reports indicate that those who have been inoculated against enteric fever, even though they may not acquire complete and lasting immunity against infection, have a decided advantage over the non-inoculated should they contract the disease ; and this in proportion to the number of times they have been inoculated. The toxin effects are diminished considerably, the complications less frequent, relapses are fewer, and the case-mortality is reduced to more than half, almost to one-third.

* Leishman : " Blood Changes following Typhoid Inoculation," *Journal of Hygiene*, 1905, vol. v. p. 380 ; also *Journ. Roy. Army Med. Corps*, 1905, vol. v. p. 1 ; also *ibid.* 1907, vol. viii. p. 463.

† Harrison : " On the Results of Experiments with Anti-typhoid Vaccine," *Journ. Roy. Army Med. Corps*, 1907, vol. viii. p. 472.

‡ Ward : " Some Notes on Anti-enteric Inoculation," *Journ. Roy. Army Med. Corps*, 1906, vol. vi. p. 436.

§ Luxmoore : " Report on the Outbreak of Enteric and Effect of Anti-typhoid Inoculation among the 17th Lancers, Meerut, India," *Journ. Roy. Army Med. Corps*, 1907, vol. viii. p. 492.

‖ *Archiv. f. Schiffs und Tropen Hygiene*, December 1905, p. 527.

ERYSIPELAS.

As a contagious and infectious disease, the chief evidence of which is a spreading inflammation of the skin, extending in some cases to the areolar tissue, and accompanied by fever, erysipelas has been known since very early times. It is met with all over the world, but less frequently in the tropics than in more temperate climes; it affects all races alike, and is especially fatal among the very young. It has been said that erysipelas is more common among women than men; this is probably true with respect to attack, but the deaths at all ages are greater among males. The total number of deaths returned from this disease in England and Wales in 1905 was 1255, of which 646 were males and 609 were females; the mortality for all ages being at the rate of 36 per million persons living, as compared with a rate of 38 per million for the last five years. The deaths from erysipelas are usually above the average from the middle of September to March, and below the average for the rest of the year. The absolute maximum for the year is commonly attained in the third week of November, while the minimum period is from the middle of June to that of September. Longstaff has pointed out that erysipelas has a mortality in inverse ratio to the rainfall, in this respect resembling scarlet fever; there is a further general resemblance in the seasonal curve of prevalence of erysipelas to puerperal fever, pyæmia, and rheumatic fever.

Etiology.—Fehleisen was the first to clearly demonstrate that erysipelas is caused by a micro-organism which he named the *Streptococcus erysipelatosus;* it is found at the edge of the inflamed skin, occupying the lymphatic channels and spreading along them as the disease advances. The cocci are from 0·43 to 0·4 μ in diameter; they are readily cultivated outside the body, and from the cultures true erysipelas can be induced in rabbits by inoculation. Associated with this streptococcus in erysipelas is usually the *Streptococcus pyogenes*, and some observers go so far as to say that they really are the same organism, the former being merely an attenuated form of the latter. The fact that two species of streptococci can be originally obtained by culture from the erysipelatous skin, and their differences proved by inoculation into rabbits, seems definitely to contradict the above supposition as to their identity. The cocci of erysipelas never enter the blood.

Formerly it was usual to regard erysipelas as occurring either with or without a wound. To a large extent this distinction between traumatic and idiopathic forms of the disease has been replaced by the belief that every case is caused by the poison entering the system through a wound, though this in some cases may be so insignificant as to be overlooked. The disease is undoubtedly infectious, but possibly less uniformly so than many of the other infective diseases.

The incubation period of erysipelas is evidently short, ranging from one to eight days, or more often from one to three or four days. In Fehleisen's inoculation cases on human beings for the removal of sarcomatous growths, the period was very short, varying from fifteen to sixty-one hours. The disease at times runs riot in hospitals, especially in surgical wards, the most important favouring circumstances being defective ventilation, overcrowding, want of cleanliness, and defective drainage arrangements. Some people seem to be more predisposed to erysipelas than others; among such are the intemperate, the badly fed, and those who have had it before. Our knowledge at present is small as to what are the precise connections between

erysipelas and the various forms of blood-poisoning, more particularly that peculiar kind of blood-poisoning associated with lying-in women or those recently confined. Evidence is strong that there is a relationship of some kind between erysipelas and child-bed fever, as shown by the familiar fact that women in labour attended by doctors or midwives who are suffering from erysipelas, or who even have been in contact with erysipelatous patients, commonly get blood-poisoning or puerperal fever. Similarly, nurses, midwives, and medical men who attend, or come into close contact with, women suffering from puerperal fever frequently themselves suffer from erysipelas; also that the new-born children of mothers ill with child-bed fever die in large numbers from erysipelas. To a less degree, erysipelas has some obscure relationship to diphtheria prevalence.

Prevention is synonymous with attention to the sanitation of hospitals and institutions, especially the maintenance of ventilation and cleanliness of wards and persons. Hospital floors should be of hard wood, polished and readily cleaned by dry rubbing or sweeping. Cases of erysipelas should be isolated, and the ward, if possible, evacuated, and the walls, floor, furniture, &c., carefully disinfected.

FOOT-AND-MOUTH DISEASE.

This is a highly contagious acute febrile disease among wild and domestic ruminants, also among pigs. It is frequently transmitted from these animals to man, and occasionally to horses, dogs, cats, and fowls.

Although this disease prevailed extensively at intervals over most parts of Europe, it was not until 1839 that it gained a footing in this country. Since then, foot-and-mouth disease has been rarely absent from Great Britain. In none of the recent outbreaks was the source of the disease traced, though there can hardly be any doubt that the contagion was brought in some way from the Continent.

The characteristic lesion of foot-and-mouth disease is a vesicular eruption on the feet and in the mouth. In milch cows, vesicles not infrequently form on the skin of the teats and udders; occasionally the eruption appears in other situations, such as the nostrils, the vulva, perineum, or the mucous membrane of the throat, stomach, or intestines. Animals infected by way of the alimentary canal may have an eruption on the feet as well as in the mouth, and an eruption in both of these situations may follow inoculation at any part of the body. The vesicles in both the mouth and feet burst, leaving ulcerated cavities which, by the access of saprophytic bacteria, may often extend into septic sores of some magnitude. In severe cases, it is not unusual to find the inflammation so severe as to lead to complete detachment of the hoof. The incubation period appears to be from five to eight days. The first symptom is dulness, shivering, loss of appetite and stiffness in movement. The characteristic signs soon follow; the animal ceases to feed, is reluctant to move, and more or less frothy saliva escapes from the mouth. If the mouth be opened, white blister-like elevations will be found on some parts of the buccal mucous membrane; these soon burst and become converted into shallow erosions. When made to move, the animal is obviously lame or tender on the feet; this tenderness of the feet is well marked even before the vesicles appear; these form on the interdigital skin or behind the hoof just above the horn. The symptoms last with little or no amelioration for a week; in uncomplicated cases all visible signs of the disease will have disappeared within another week or ten days. Young

animals recover much more rapidly than older ones. In sheep and pigs the lameness and feet symptoms predominate.

Little is known as to the nature of the infective agent; Löffler and Frosch * have demonstrated its ability to pass through a porcelain filter, consequently it is probably ultra-microscopic. It is not only invisible, but also uncultivable by any artificial means hitherto employed. Whatever the germ may be, it is very infectious, attaching itself readily to hands, clothing, bedding and other materials. The agent of infection appears to be abundantly present in the fluid from the vesicles, and in the discharge from the ulcers left by the vesicles when they burst. The buccal saliva is highly charged with the virus from the first appearance of the eruption in the mouth. On the other hand, the blood is not infective after the development of the eruption; it is before. Animals are probably infected by direct contact, or by straw and mangers. The transmissibility of the disease to man is proved by many well-attested cases. Milk and direct inoculation are probably the chief modes of infection.

GLANDERS.

It is probable that this disease is much more common in man than the statistical returns would suggest; it is, however, extremely common among horses, mules, asses, and other animals. Hunting † is of opinion that at least two thousand horses die of glanders annually in this country; this is possibly an under-estimation. The disease may be described as a sub-acute, infectious disease of the nasal mucous membrane, respiratory organs, and skin; when localised in the skin, the affection is termed *farcy*, but this is identical with the more ordinary form. Whether affecting man or animals, glanders is remarkably fatal. In the human subject the disease is met with in two forms, an acute and a chronic. The site of inoculation is usually on the hand or arm, by means of some scratch or abrasion, sometimes on the face, and occasionally on the mucous membrane of the mouth, nose, or eye. In the acute form there appears at the site of inoculation inflammatory swelling, attended with redness and swelling of the lymphatics. The local changes are followed by marked constitutional disturbance. In the chronic form the local lesion results in the formation of an irregular ulcer with thickened edges and sanious discharge.

The chief source of infection is undoubtedly the horse. The virus does not appear to be capable of aerial transmission, except, perhaps, for very short ranges. Among horses, ingestion is probably the chief mode of infection, the disease being spread by means of nose-bags, halters, pails, mangers, and other objects to be found in stalls and stables. So far as man is concerned, inoculation through a cutaneous wound is regarded generally as the chief mode of infection; it is questionable whether this is so. As Hunting has pointed out, the ways of horse-keepers are not aseptic, and it is probable that ingestion is more often the mode of infection in man than inoculation. Meals are eaten in the cab and stables with unwashed hands, and the nasal discharges from glandered horses have frequent opportunity to be transferred to the men's food. The usual incubation period is from three to eight days, but in acute cases may be shorter.

The cause is a bacillus, usually present in the nodules, being more

* Löffler and Frosch: *Centralbl. f. Bakter. u. Parasitenkunde*, 1898, vol. xxii. p. 371.

† Hunting: "Glanders in Horse and Man," *Trans. Epidem. Soc. London*, N.S., 1905–6, vol. xxv. p. 141.

numerous before these latter have become purulent. The bacilli are slender rods with rounded ends, resembling both in size and appearance the tubercle bacillus. They are easily cultivated at 35° to 38° C. on blood-serum, agar, potatoes, and other media. On boiled potato at 35° C. they form on the third day a transparent layer of slightly yellowish tint, like clear honey in appearance. On subsequent days the growth becomes darker and more opaque, and on the eighth day it has a reddish brown or chocolate colour which is very characteristic. Inoculations of these artificial cultures into horses and asses produce typical glanders. The bacilli appear to be killed by drying, and by ten minutes' exposure to 55° C.; in this respect they are less resistant than many non-spore-bearing bacilli. Corrosive sublimate (1 : 5000) kills them in two minutes, and 5 per cent. carbolic acid in five minutes.

The injection into horses, suffering from glanders, of chemical substances obtainable from cultures of the bacillus (mallein) produces a well-marked rise of temperature; but no reaction follows in healthy horses. Mallein is prepared in the same way as tuberculin, and affords in doubtful cases a ready means of determining the diagnosis of glanders.

Prevention will be best secured by early isolation of the infected man or animal. All discharges from the nasal and respiratory mucous membranes should be disinfected and destroyed. Infected stalls and stables should be disinfected. Glandered horses should be destroyed, but this is not compulsory in the case of farcy. Though there is no evidence that the flesh of glandered animals used for food propagates the disease, still it is advisable that it should not be consumed.

The regulations at present in force for the control of glanders in animals are inadequate. They provide compulsory notification by the owner or occupier, diagnosis by a veterinary inspector, and slaughter, with compensation, of all diseased horses. They do not, however, provide for any action over the in-contact animals. A stable of a hundred horses may show a case of glanders every week for months, a condition which renders it certain that many are infected, though not visibly diseased. At any time this stock may be sold and carry unsuspected infection into a dozen other establishments. The ability of the disease to remain latent in the horse and other equines for considerable periods of time constitutes one of the difficult features of the problem how to stamp glanders out.

The Glanders or Farcy Order of 1907, issued by the Board of Agriculture, lays down compulsory notification of actual or suspected disease to the police; empowers a Local Authority to slaughter at once any diseased horse, ass, or mule; and, further, enables the Local Authority to test suspected animals with mallein and to deal with the contact animals. This Order is a notable advance on the previous Statutory Order of 1894, and should do much to control the spread of glanders. The Order extends to England and Wales, and Scotland, and its provisions come into force on January 1, 1908.

HYDROPHOBIA.

From very early times it has been known that dogs are liable to a fatal disease which they transmit by their bite; and this disease when occurring in man was called "hydrophobia," from the dread of water, which is one of its chief symptoms. In the lower animals, however, this very symptom is absent, hence in them it is more commonly spoken of as rabies.

Rabies may occur in many kinds of animals besides dogs. It is common

in wolves, jackals, and foxes, and the bite of a rabid wolf is notoriously the most dangerous of all. Cats are sometimes affected by it, but far less frequently than dogs. Among herbivora, horses, oxen, sheep, goats, deer, pigs, rabbits, and guinea-pigs are capable of being infected experimentally by inoculation, or if they are bitten by rabid dogs.

There are two varieties of the disease in dogs; one characterised by maniacal excitement, the other by paralysis of the jaw, so that it hangs down and allows a frothy saliva to run out of the mouth. In each form the bark is somewhat altered. Towards the last, the hind legs and the loins become paralysed so that the animal staggers about and falls. Rabies is always fatal in dogs, usually in a week after the symptoms have appeared, occasionally after nine or ten days. In rabbits the symptoms of rabies (transmitted from dogs), in the absence of excitement and the development of paraplegia, are like those of dumb madness, which, as in dogs, takes the form of acute ascending paralysis. The study of the disease when reproduced by inoculation in animals shows a very similar series of symptoms to those which are characteristic in man. There is first a stage of excitement with visual delusions; then hyperæsthesia with reflex spasms; next the stage of mania and (particularly in rabbits) paraplegia, corresponding to the dumb rabies of dogs; and lastly, death, often by sudden failure of the heart.

At one time hydrophobia was supposed to occur chiefly in temperate climates, but this is not the case, as it is by no means uncommon in India and Central Asia. Like other specific diseases it is often absent from a town or locality for several years together, until some accident introduces it and it becomes epidemic. Of recent years this country has been remarkably free from hydrophobia, only two cases having occurred in the human subject since 1898; both of them were in 1902. This immunity is due to the careful application of the muzzling order and of the rigid licensing laws concerning dogs. It was not so formerly, as in the ten years 1889–98, there were 104 deaths from the disease, thirty being in 1889 and twenty in 1895. After this, the muzzling order was enforced strictly with the very best of results.

According to the popular belief, the disease is more frequent in the hot season than during winter and spring. Of 132 cases throughout England and Wales, fifty-one occurred in July, August, and September. Hydrophobia caused most deaths at ages between five and fifteen years, more males being affected than females. Bites about the face, and especially those inflicted by rabid wolves, are more deadly than others; the danger is less when the part bitten is protected by clothing. Of cases of bites by animals proved beyond doubt to be rabid (the proof being the occurrence of a genuine case of rabies in some person or animal bitten by them or inoculated from them), hydrophobia manifests itself in 20 to 25 per cent. of the persons bitten, all of whom die. By means to be described subsequently, the mortality may be reduced to at least 0·18 per cent., and by other preventive measures the disease can be and has been stamped out completely.

Hydrophobia is doubtless caused in all cases by the transference to the patient of the specific virus of rabies, such transference being imparted to man and probably animals also by the bite of rabid dogs; or more rarely of rabid wolves, jackals, foxes, and cats. The *incubation period* is most frequently about six weeks. When the infecting wound is on the face, the incubation is probably shorter. In children, also, it is usually shorter than in adults. In 132 cases of hydrophobia, selected by the Registrar-General (1886) on account of the circumstances being accurately known, the shortest

incubation was eleven days in a child bitten by a rabid cat. In 23 cases it was under a month, in 64 between one and two months, in 21 between two and three months, in 124 it was under five months, in 127 under ten months, and in 130 under two years. In one case it was between three and four years, and in one other above four years. Experimental inoculation in dogs, rabbits, and other animals shows, on the whole, shorter periods than when the disease dates from the infliction of a bite by a rabid dog ; and when the virus is introduced, not subcutaneously, but beneath the dura mater after trephining the skull, the period of incubation is measured by days, a week being a very frequent time.

There is no doubt that the virus resides in the saliva and salivary glands. Magendie long ago produced rabies in dogs by inoculating them with the saliva of hydrophobic patients. Pasteur demonstrated that the spinal cord is also the seat of the virus, and that inoculation from it, especially if introduced under the dura mater of a dog or a rabbit after trephining the skull, will reproduce the disease in dogs and rabbits. Pasteur further showed that the virus, when propagated through a series of rabbits, increases rapidly in its virulence ; so that whereas subdural inoculation from the brain of a mad dog takes from fifteen to twenty days to produce the disease, in successive inoculations in a series of rabbits the incubation period is gradually reduced to seven days. The spinal cord of these rabbits contains the virus in great intensity, but, when kept in perfectly dry air, the virus gradually diminishes in intensity. If, now, dogs are inoculated with cords preserved for from twelve to fifteen days, and then with cords preserved for a shorter period, *i.e.*, with a progressively stronger virus, they gradually acquire immunity against the disease. A dog treated in this way will resist inoculation with material from a perfectly fresh cord from a rabid rabbit, which otherwise would inevitably have proved fatal. Relying upon these experiments, Pasteur began inoculations in the human subject, using, on successive days, material from cords in which the virus was of varying degrees of intensity. The results have been remarkably satisfactory, even in cases where the bites have been severe and on exposed parts, such as the hands and face. The percentage mortality of all cases in which the Pasteurean treatment was completed, for the last five years stands as 0·37 in 1901, 0·18 in 1902, 0·65 in 1903, 0·66 in 1904, and 0·54 in 1905. Recently, a serum treatment has been introduced by Babes ; * at present it is still in its infancy, but the experimental results with animals are so striking that we are justified in hoping for similar, if not better, success in the treatment of hydrophobia in man.

Prevention.—Rabies can be stamped out by muzzling all known dogs for a sufficient length of time, and destroying all others. This was done in Sweden many years ago, and the country remains free from hydrophobia. The same is the case in Berlin. In England, several local attempts have been made in the same direction, notably in 1885 in London, in 1886 in Nottingham, and in 1890 throughout Lancashire, Cheshire, the West Riding of Yorkshire, and London. These muzzling orders have always been followed by a cessation of rabies, but have been invariably relaxed too soon. The only effectual way to stamp out rabies is to enforce muzzling strictly throughout the island for at least a year. Under the Rabies Order of 1892, issued by the Board of Agriculture, County Councils have power to make regulations for muzzling and other preventive measures.

* Babes : *Ann. de l'Institut Pasteur*, 1889, vol. iii. p. 384 ; *also* 1894, vol. viii. p. 435. Consult also Tizzoni and Centanni : *Lancet*, 1895, vol. ii. pp. 659, 727, 780. For further literature on this subject, reference may be made to Woodhead's article on Hydrophobia in Allbutt's and Rolleston's *System of Medicine*, 1906, vol. ii. Part. I., p. 813.

INFLUENZA.

The recent series of epidemic visitations of this disease in this country have made its chief characteristics familiar to most people. Although the original home of this affection is not known, our knowledge is sufficient to convince us that it is a disease which has periodically prevailed in various parts of the world as an epidemic since very early times. An analysis of the chief epidemics of influenza during the present century shows that its progress and prevalence are quite independent of race, climate, or season; that man is the chief vehicle of its diffusion; and that its epidemic prevalence attains its height amongst crowded communities. Although there is some indication of its preference for lines of traffic, the actual progress of an epidemic is very irregular.

The interval between epidemics is variable; in England the chief outbreaks were in 1803, 1833, 1837–8, 1847–8, and some minor epidemics about every three years till 1860, when these practically ceased. Nothing was heard of the disease after 1860 until 1889, when a new series of epidemics began, each covering almost the whole country at intervals of about a year. Influenza epidemics differ in type from time to time, and there is also considerable variety in different centres during the progress of an epidemic as to the tendency to one or other group of local symptoms or complications. All epidemics, however, present the same general characters, such as "rapidity of dissemination, general independence of climatic, seasonal, age and sex influences, relative suddenness of onset as regards attack, and low case mortality" (Parsons).

When the 1889 epidemic appeared in England some doubt was expressed by a few as to whether it was influenza at all, mainly owing to the improper and traditional application of the term "influenza" during non-epidemic times to ordinary catarrh. Others were disposed to complicate the situation by the suggestion that the prevailing epidemic was one of dengue. This latter is, however, "essentially a disease of hot climates and season, seldom fatal, is unattended with pulmonary complications, almost always presents a rash, and is frequently followed by desquamation."

Mortality.—The following table shows the rate of mortality from influenza, in England and Wales, during recent years. The figures are crude annual death-rates for all ages per million living of each sex.

Year.	Males.	Females.	Year.	Males.	Females.
1890	173	142	1898	329	332
1891	612	538	1899	395	385
1892	537	530	1900	493	514
1893	334	317	1901	185	163
1894	222	218	1902	228	218
1895	419	427	1903	190	189
1896	128	116	1904	170	166
1897	205	187	1905	205	202

Experience shows that a rise in the mortality from influenza has been attended generally by a rise in the mortality from lung, and sometimes heart, disease. During the years 1890–1–2–3 this was specially conspicuous, so that the mortality attributable to influenza must therefore not be measured solely by the deaths registered as due to that cause, but the indirect effect of the malady as expressed in the increased death-rate from

certain other causes must also be taken into account. The case mortality is variable, but generally low, averaging about 1 to 0·6 per 1000.

The *protection* conferred by an attack is slight and evanescent, second and third attacks being common.

As illustrative of the change in the age incidence of fatal influenza since 1847–8, the following table is given by Tatham ; the figures represent rates of mortality per million living at the several age-groups :—

	Under 5 years.	5–10	10–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85 and upwards.
1847–1848	713	80	49	51	79	139	284	809	2372	5510	11243
1890–1903	251	43	36	84	137	244	424	861	1891	3674	6171

Etiology.—The period of incubation appears to be short, from one to three days. The breath is in all probability infectious from the first, continuing to be so as long as the eighth or tenth day, and perhaps longer.

Various hypotheses have been proposed to explain the cause of influenza, but in the light of what we know about other diseases, coupled with the general behaviour of influenza, the most probable one is that it depends upon a micro-organism. Though various species of bacteria have been described by different observers as present in this disease, those first described by Pfeiffer in 1892 as being constantly present in the bronchial sputum and pulmonary exudation in all cases of influenza are now generally regarded as the real microbial cause. The bacilli are very minute, about half the length but the same thickness as the bacilli of mouse septicæmia ; in stained specimens they show a characteristic bipolar granule with intermediate clear part, hence closely resemble a diplococcus. They aggregate in clumps, occur in the leucocytes of the sputum, and disappear with the cessation of the disease. At 37° C. they grow in a characteristic manner on blood-agar. Colonies appear within twenty-four hours in the form of minute circular dots almost completely transparent. When numerous the colonies are scarcely visible to the naked eye, but when sparsely arranged they may reach the size of a pin's head. A very small amount of growth takes place in broth, but when blood is added a thin whitish deposit forms at the bottom of the tube. The bacilli are found in enormous numbers in the sputum of influenza, but only occasionally in the blood. It is probable that the chief symptoms are due to toxins absorbed from the respiratory tract.

The curious tendency of influenza to recur at intervals in the same locality is suggestive that the contagion may be able to live and thrive for considerable periods outside the human body ; but whether this is in the soil or in the bodies of domestic animals is unknown. That these latter creatures, particularly dogs and cats, suffer during influenza epidemics from symptoms extremely like it is generally accepted. Horses, also, are liable to a severe and often fatal disease, known as "pink-eye," which has been regarded as a form of influenza. There are, however, reasons for doubting the transmissibility of influenza to lower animals.

Prevention.—Isolation should be carried out from the earliest appearance of symptoms. During periods of epidemic prevalence, people should not congregate together, and public meetings should be avoided as much as possible. A regular life, plenty of open-air exercise short of fatigue, a proper number of hours in bed, and regular meals of good, simple food are among the best prophylactics.

KALA-AZAR.

This is a chronic and fatal fever of an irregularly remittent type occurring in an epidemic form in Assam, and in an endemic form in some parts of India and other tropical countries. The disease is characterised by debility, anæmia, wasting, progressive enlargement of the spleen, with a tendency to hæmorrhages and dropsical affections.

A knowledge of the existence of Kala-azar dates back to about 1869, but the disease did not attract especial attention until 1882, when it attained epidemic proportions in Assam, depopulating certain areas in the Garo Hills, and spreading slowly up along both banks of the Brahmaputra. Earlier attempts to determine the nature and cause of the disease were marked by most diverse hypotheses. By some, for example, it was supposed to be a form of uncinariasis, by others a severe form of malarial cachexia, while various epidemics of what we now know to have been the same thing, occurring in other parts of India than Assam, were designated variously Dum-dum fever, Burdwan fever and Kala-dukh.*

Etiology.—Although there are still important gaps to be filled, there is little doubt that the cause of this disease is the parasite first described by Leishman,† and known variously as Leishman-Donovan bodies or *Leishmania donovani*. These organisms, in the form of small oval or round bodies, about the size of a blood-plate, with a rounded macro-nucleus and a smaller rod-shaped micro-nucleus, are to be found in the large endothelial or macrophagic cells of the spleen and bone marrow as well as in various other parts of the body. The full life-cycle of this parasite is not known, but it probably represents the resting or asexual stage of a flagellate whose sexual development is completed in an invertebrate intermediary host. The most that is known at present of this change is that, under suitable conditions of artificial culture, the parasite develops into a flagellate suggestive of *herpetomonas*.

The epidemiological facts indicate that the disease is spread by human intercourse, and although natives are the chief sufferers it is becoming increasingly evident that Europeans and Eurasians are frequent victims. Sex, age, and season of year do not appear to be factors influencing at all the incidence of Kala-azar. As regards the mode of elimination of the parasite from the body, several alternatives have been suggested; these are, by the bowel, by the urine, by the bronchial secretion, by the skin, and by the blood. The weight of evidence is in favour of this last method, the parasites being withdrawn from the blood by some blood-sucking insect. Rogers attaches great importance to this hypothesis, in fact goes so far as to say that the bed-bug is the invertebrate host. If Patton's work is confirmed this would seem to be the probable solution of the question; the intermediate host being the Indian bed-bug, *Cimex rotundatus*. The paucity of the parasites in the peripheral blood constitutes the chief difficulty in believing this method of transmission to account for infection in all cases. Of the other possible channels of elimination, those by the bowel and skin are worthy of note. It is true these parasites have never been found in the intestinal discharges, but the fact is beyond dispute that they are present in intestinal ulcers. Similarly, Wright has demonstrated the presence of analogous parasitic

* Rogers: "Milroy Lectures on Kala-azar," *Brit. Med. Journal*, 1907, vol. i. pp. 427 and 557.

† Leishman: *Brit. Med. Journal*, 1903, vol. i. p. 1252, vol. ii. p. 1376; 1904, vol. i. p. 303, vol. ii. pp. 29 and 642.

forms in tropical ulcers or oriental sore, which by some, possibly on insufficient evidence, is regarded as nothing but an attenuated and local infection of Kala-azar.

Prevention.—Until the complete life-history of the parasite is worked out and we know how it leaves and enters the body, it is difficult to dogmatise as to prophylaxis. In the epidemic manifestations of Kala-azar, good results have followed the complete segregation of all recognised cases, with their families, combined with thorough disinfection of quarters, clothing, and furniture. In the case of coolies or other native races living in primitive habitations, complete abandonment and destruction by fire of all their quarters and belongings seems to be the surest and quickest means of stamping out infection. According to Rogers, this practice has been most successful on several tea estates in Assam.

LEPROSY.

This is a chronic infectious malady characterised by either the presence of tubercular nodules in the skin and mucous membranes, or by degenerative changes in the nerves. At first, these forms may be separate, but ultimately both are combined. Leprosy is one of the oldest of known diseases, and at present prevails widely, particularly in hot countries. In India, it is estimated that there are some 300,000 lepers. In Europe, where it extensively prevailed in the Middle Ages, it has become almost unknown except in Norway. In America it exists in the Gulf States and in Mexico. In the Sandwich Islands leprosy has developed to an enormous extent; while in the West Indies the disease has been long endemic.

Cause and Etiology.—A microscopic section made through a leprous tubercle shows the tubercle to be a granuloma, each and all of the cells of which are filled with minute bacilli. Hanson was the first to observe this fact, and regarded these bacilli as the virus of the disease. These observations have since been repeatedly confirmed by others. The lepra bacilli are on the average 4 to 8 μ long, and about 0·8 μ thick; in well-stained and well-washed specimens they resemble somewhat the tubercle bacilli, by showing segregation of the protoplasm (deeply stained granules) in a faintly stained sheath. Cultivations of these bacilli have not been satisfactorily carried out; while all inoculation experiments on animals have yielded only negative results.

Leprosy attacks all classes and persons of all ages. It is probably communicated by contagion, but contagious only in the same sense as syphilis, and just as accidental contamination with this virus is extremely rare, so it is with leprosy. The closest possible contact may take place for years, as between parent and child, without transmission; but it is difficult to explain the rapid spread of the disease in the Sandwich Islands on any other view than contagion, and yet it is strange that there is no evidence of a primary lesion or external sore comparable to that of syphilis. Black * has suggested that the original lesion is in some part of the extensive nasal mucous membrane. The disappearance of the disease in the Middle Ages was probably the result of the strict isolation of lepers enforced at that time. In more recent times, it is just possible that the affection may have been transmitted by vaccination, though there is no authentic case of such having happened. Hereditary transmission cannot be excluded, and there

* Black: "The Pathology and Treatment of Leprosy," *Lancet*, 1906, vol. ii. p. 1064.

is no good reason why the disease should not be communicated, like syphilis, from parent to child. Hutchinson believes that the disease is always associated with some special kind of food, particularly fish. He does not deny the specific nature of leprosy, or the possibility of contagion, but infers that it may be the fish diet which renders the patient susceptible, or even be the vehicle or medium with which the poison may be taken. So far, the general facts regarding the incidence of this disease do not lend much support to Hutchinson's views, but rather indicate the importance of keeping lepers as much isolated as possible, and otherwise treating it as being essentially a communicable disease.

Prevention probably depends upon the removal of children of leper parents from the leprous surroundings, and their education in separate orphanages under favourable hygienic conditions. The voluntary isolation of lepers in colonies or farms should be encouraged, and the abstention of lepers from the occupations of barbers, clothiers, laundry-workers, and sellers of food-stuffs should be compulsory. Harsh measures of complete compulsory segregation are probably unnecessary, and, although matrimony and sexual intercourse should obviously be discouraged, there is no real justification to add further to the miseries of lepers by separating husband and wife, or even, in some cases, by prohibiting the marriage of lepers. In reference to this question, the following conclusions were adopted at the International Leprosy Conference at Berlin, in 1897.

(1) In countries where leprosy forms foci or has a great extension, isolation is the best means of preventing the spread of the disease.

(2) The system of obligatory notification, of observation and isolation as carried out in Norway, is recommended to all nations with local self-government and a sufficient number of physicians.

(3) It should be left to the legal authorities, after consultation with the medical authorities, to take such measures as are applicable to the special social conditions of the districts.

MALARIA.

The malarial diseases may be conveniently considered as a single group, although they include many varieties that have received names suggestive of specific distinctions between them. They all have a characteristic tendency to periodicity, and in their general etiological conditions are closely related.

Geographical Distribution.—" Covering a broad zone on both sides of the equator, malarial diseases reach their maximum of frequency in tropical and subtropical regions. They continue to be endemic for some distance into the temperate zone, with diminishing severity and frequency towards the higher latitudes ; in epidemic form they not infrequently appear in yet other regions, and in still wider diffusion with the character of a pandemic also beyond their indigenous latitudes " (Hirsch). The present distribution of malaria indicates it to be widely prevalent in a virulent form in tropical Africa, especially on the west coast. It also prevails in Algiers, and in the Nile Valley of Egypt. In Asia, it is notoriously prevalent in India, China, Ceylon, Arabia, Afghanistan, Persia, and Syria. In the western hemisphere, it is met with in the West Indies, Peru, Brazil, Panama, and the southern and central parts of the United States. Of European countries, Italy suffers the most, and perhaps Great Britain the least, though even now the disease still lingers in the fen districts of Lincolnshire, and the counties of Norfolk, Huntingdon, and Cambridge.

Although malaria is most prevalent and most malignant in tropical and subtropical countries, yet among such countries it appears to have a special affinity for certain parts. Thus, in India, the Presidency of Madras suffers much less than those of Bengal and Bombay. So, also, on the West African coast, malaria "becomes less severe from Cape Lopez southwards, and this exemption becomes more and more marked the nearer we approach the Cape of Good Hope, which itself enjoys, along with St. Helena, an almost complete immunity from the endemic fever." New Zealand and Tasmania are said to be completely, and Australia almost completely, exempt.

As regards sex and age influence, males appear to suffer more frequently than females, but possibly this is due to increased exposure to infection. No age can be said to be exempt, but attacks are certainly less frequent among the very young and the very old.

Influence of Season and Locality.—Although in countries where malaria is endemic the disease occurs in any season of the year, its general prevalence, nevertheless, appears everywhere to be largely regulated by season, though the particular time of year in which it is most common varies in different countries. Even in the tropics, where malaria constantly prevails, there are minimum and maximum periods; the former corresponding to the summer and winter, the latter to the spring and autumn months. In temperate climates there are only a few cases in the spring, but a large number of cases in September, October, and sometimes in November. In the most malarious districts in the tropics, the maximum prevalence is during and towards the close of the rainy season. In the temperate climates the relation between the rainfall and malaria is not so clear, the cases being often more numerous after a dry summer. A tolerably high temperature appears to be one of the essential conditions for the prevalence of the disease.

The importance and influence of soil states in the etiology of malaria has been much misunderstood in the past; the point has been discussed in a previous chapter, and resolves itself mainly into a recognition of how far local conditions are favourable or unfavourable to the breeding of mosquitoes. This fact explains why the disease is common in low, marshy regions, the beds of old rivers, and badly drained districts.

Immunity.—The existence of a natural immunity to malaria is suggested by the relative insusceptibility of some dark races to the disease, by the exemption of certain persons who live in malarious districts and are constantly exposed to infection, and by the difficulty experienced in transmitting the disease to some individuals by the inoculation of malarial blood. Generally speaking, one attack of malaria does not protect against subsequent infection, but occasionally, severe and repeated attacks do result in a partial or complete immunity. Probably the relative immunity of some dark races is due to the great frequency of infections during their childhood.

Etiology.—The infective agent of malaria is one or other of the following species of protozoa, namely, *Plasmodium malariæ*, the quartan parasite; *Plasmodium vivax*, the tertian parasite; and *Plasmodium immaculatum*, the parasite of pernicious malaria. These parasites are introduced into man by the bite of mosquitoes of the sub-family anophelinæ of the culicidæ, which have themselves become infected by biting individuals whose blood contained gametes of the malarial parasites. The life-history of this parasite has been explained. At the present time the following mosquitoes have been shown to be capable of transferring malarial infection:—*Anopheles bifurcatus* in Europe; *A. maculipennis* in Europe and North America; *A. Jessensis* in Japan; *A. Martini* and *A. purcati* in Cambodia;

A. Vincenti in Tonkin; *Myzomyia Christophersi* and *M. culicifacies* in India; *M. funesta*, *M. superpicta*, and *Myzorhynchus paludis* in West Africa; *M. Constani* in Madagascar and Reunion; *Pyretophorus costalis* in Africa; *Nyssorhynchus Lutzi* in Brazil; and *N. cubensis* in Panama. Doubtless numerous other Anophelinæ transfer the disease. The situation, therefore, amounts to this, that malaria does not occur spontaneously without the presence of anophelinæ, the existence or recent presence of cases of malaria from which the mosquitoes may derive the infection, climatic conditions favouring the activity and susceptibility of the mosquito for the full development of the parasitic oocysts. In the absence of any one of these factors an outbreak of malaria is impossible.

Prevention.—In view of the etiology of malaria, its prophylaxis is partly personal and partly public. Personal prophylaxis will consist, in the first place, of precautions to avoid being bitten by infected mosquitoes; this entails the careful use of mosquito-curtains in the sleeping-room, the provision of wire-gauze screens to all doors and windows, coupled with the wearing of veils over the hat and head when exposing oneself at night in places where infected mosquitoes exist or are suspected to exist. Periodical and frequent fumigation of rooms with formalin will do much to kill adult mosquitoes and drive them away from dwelling-places. To these precautions must be added care to live at a distance from infected people, such as native children and others, supplemented by the taking of quinine for the destruction of parasites which may have gained an entrance into the blood.

The public prophylaxis of malaria, though theoretically identical for every place is, in practice, rarely feasible in its entirety for all localities. Where possible, the detection, isolation, and cinchonisation of the infected is of the first importance. This method is practicable for relatively small communities, but difficult to carry out properly in populous malarial districts. The main difficulties in the way of this policy will be the cost and the inertia of an ill-informed public. The same objections arise in respect of any organised attempt to segregate the healthy or to provide mechanical protection in houses and public buildings from mosquito bites. The chief lines of action in the direction of public prophylaxis against malaria must be towards the reduction of mosquitoes. This can be effected by the Local Authority without co-operation of the public, and benefits, not a few individuals, but the whole community. The necessary measures are permanent and annual. The first consist of works of drainage or the filling-up of pools, ponds, and marshes, the rectification of water-courses and similar engineering efforts; the second involve the constant services of a sufficient staff for preventing the formation of rain-water pools and the accumulation of water in drains, gutters, tubs, and other vessels. Complete suppression of mosquitoes is probably impossible, but anti-malaria campaigns organised on these lines to minimise the breeding and spread of mosquitoes have been productive of great good at Ismailia, Klang, Port Swettenham, Panama, and Havana. The success in these places has been remarkable, so much so that the persistence of much malaria in tropical towns can only be looked upon as proof of sanitary maladministration.*

* Ross: "The Logical Basis of Mosquito Reduction," *Brit. Med. Journal*, 1905, vol. i. p. 1025; also *Nature*, June 15, 1905. See also "An Address on the Prevention of Malaria," delivered at the Internat. Congress of Hygiene, Berlin, 1907. *Lancet*, 1907, vol. ii. p. 879.

MALTA FEVER.

Malta or Mediterranean fever, so called from its prevalence in those parts, has long been known to exist in many other parts of the world as well. It is a disease of long duration, averaging four months, but in some cases dragging out its course for one or two years. The temperature curve is characterised by extreme irregularity, fresh exacerbations of fever being frequent. Another prominent feature of this fever is the occurrence of painful and swollen joints, neuritis in various nerves, accompanied by extreme anæmia and debility. Our earlier knowledge of the clinical and epidemiological facts concerning this disease is derived from the writings of various officers of the Army Medical Service, notably of Marston * and Veale.† In their day, the disease was considered to be of the nature of malaria and returned usually as remittent fever; but the more severe cases were often returned as enterica, while the milder ones were scheduled under such names as febricula or simple continued fever. The next event of any importance was the discovery of the specific organism of the disease in 1887 by Bruce,‡ and named by him as the *Micrococcus melitensis*. Ten years later, fresh work on the disease by Wright and Semple § helped greatly to facilitate the differential diagnosis of the affection from enterica, malarial and other acute specific fevers. About the same time, Hughes || published a complete summary of the subject as then known, with much information as to the clinical features of the disease.

Influence of Climate and Season.—Although deemed by earlier writers to be a disease limited to Malta, recent investigations show this affection to be very widely distributed. Undoubted cases have been reported not only from Malta, Gozo, Sicily, Crete, and Cyprus, but from Gibraltar, Tunis, Algiers, Italy, Greece, Turkey, Egypt, Palestine, Aden, various parts of India, China, Abyssinia, South Africa, the Philippine and Fiji Islands, North America in the Mississippi Valley, Cuba and Venezuela, Brazil and Montevideo. From these facts it is clear that the epidemiological incidence of Malta fever is widely spread in tropical and sub-tropical countries.

In regard to other etiological factors, such as the influence of age and sex, of occupation, length of residence and climatic conditions, our chief information relates to Malta itself, where the most extended series of observations have been made. These indicate that the disease prevails among the civil population of the island more in the rural than the urban districts. In the naval and military garrison, the incidence is greater among officers and those of a superior social class than among the men. Among soldiers, the average yearly incidence is 37 per 1000 of strength, while among the sailors of the fleet it is 28 per 1000 of strength. There is little evidence to show any relation between the disease and age, sex, occupation, length of residence or general sanitary environment. On the other hand, there is a very close correspondence between the curve representing

* Marston: "Report on Malta Fever," *Army Medical Report*, 1863, vol. iii. p. 486.

† Veale: "Report on Cases of Fever from the Mediterranean," *Army Medical Report*, 1881, vol. xxi. p. 260.

‡ Bruce: "Note on the Discovery of a Micro-organism in Malta Fever," *Practitioner*, September 1887; also *idem.*, April 1888; *also* "On the Etiology of Malta Fever," *Army Medical Report*, 1892, vol. xxxii. p. 365.

§ Wright and Semple: "On the Serum Diagnosis of Acute Specific Fever," *Brit. Med. Journal*, 1897, vol. i. pp. 139, 258 and 1214.

|| Hughes: *Mediterranean, Malta or Undulant Fever*, London (Macmillan), 1897.

the temperature and that representing the number of cases. This latter rises at an interval of about a month following the former, and approximates sufficiently to allow for the incubation and notification if the incidence of the fever were directly dependent upon air temperature. The case curve attains its maximum in July–August, but, unlike the temperature curve, it at once commences to drop, so that it would appear that whatever connection the air temperature may have with disease incidence, it does not remain so obvious after the former has attained its maximum. The curve representing rainfall in Malta is, in general, the inverse of that representing temperature. The curve of incidence commences to drop at the same time as the rainfall curve rises, allowing no interval for incubation and notification, so that the connection between the two is not clear.

Etiology and Infectiveness.—The cause of Mediterranean or Malta fever is undoubtedly the *Micrococcus melitensis.* This coccus or cocco-bacillus is about 0·3 μ in diameter, and occurs usually singly or in pairs, but when grown in broth it appears in short chains. A bacillary form occurs in cultures which have been grown at 18° to 20° C. The length of these bacilli is about three times their breadth, some are somewhat curved, but all are non-mobile. The micro-organism stains by ordinary basic dyes, but decolorises by Gram. Its growth on artificial media is slow, and it is of importance that only faintly alkaline media be used. It grows best at 37° C., scantily and usually as a bacillus at 18° C.; at temperatures between 40° and 42° C. its growth is suspended. On plates the colonies take some three days to grow; the whiteness of the almost hemispherical colonies by reflected light, and the clean, bright brown translucency by transmitted light are very characteristic. In broth, the growth is a uniform turbidity without pellicle. Milk is not clotted. In glucose or lactose peptone, no gas is produced, only alkalinity. On both blood serum and potato, a moist white growth takes place. This micrococcus can be distinguished from all other microbes by its slow growth on both agar and gelatin, the latter not being liquefied. Its transparent dew-like colonies on agar, becoming slowly denser and yellowish brown in colour, are characteristic; other distinguishing features are its microscopical characters and its behaviour to specific serum.

To the work of a Commission sent to Malta in 1904 by the Royal Society at the request of the Admiralty, War Office, and Colonial Office, we owe much of our knowledge regarding the life-history of this micro-organism of Malta fever.* The principal path by which this micrococcus leaves the human body is by way of the urine. It also leaves the body by way of the blood, by the agency of mosquitoes and other biting insects, but this only rarely and in very small numbers. The urine, on the other hand, sometimes contains the micrococci in enormous numbers; about 10 per cent. of urine samples were found to contain this micro-organism. A variety of experiments made by the Commission show that the coccus is fairly resistant to external influences. It can resist in a dry condition, in dust or in clothing, for two to three months. It lives in tap-water or sea-water for about one month. Even in urine which has decomposed and become alkaline it can live for a week. Exposure to direct sunlight kills it in a few hours.

In order to solve the question, How does the micrococcus gain entrance to the body? a variety of experiments were made by the Commission in

* Report of Commission on Mediterranean Fever, appointed by the Admiralty, the War Office, and the Civil Government of Malta, under the supervision of an Advisory Committee of the Royal Society, 1905 and 1906. See also *Journ. Roy. Army Med. Corps*, vol. v. pp. 77, 171 and 311; *also* vol. vi. pp. 381, 487 and 623; *also* vol. vii. pp. 1, 93, 245, 307, 419 and 531.

regard to contact, effects of dust, feeding, and the bites of insects. Those in respect of contact were made by placing monkeys in more or less intimate contact, and it was found that if the contact was quite intimate, infection does take place. If, on the other hand, the contact is less intimate, so that contamination of the food by infected urine was prevented, infection did not take place ; in fact, these contact experiments resolved themselves into feeding experiments. As it is unlikely that man has his food so grossly contaminated as in the case of the monkey, it is improbable that infection takes place, except most rarely, in this way. The dust-infected experiments were entirely negative, forcing the conclusion that conveyance of the infective germ by means of contaminated dust could rarely, if ever, give rise to the disease. The possibility of infection by the mouth had been shown in the contact experiments ; others, specially designed, proved abundantly that Malta fever can be conveyed to healthy animals by way of the alimentary canal, even a single drink of fluid containing a few micrococci almost certainly giving rise to the disease. As regards infection by insects, it had long been known that the smallest quantity of the micrococci introduced under the skin, or applied by a scratch, would give rise to the disease in man and monkeys ; the Commission re-investigated this point, and their experiments show that this mode of conveyance by mosquitoes or other biting insects of micrococci from the sick to the healthy, if not absolutely negatived, can only be of the rarest occurrence.

Up to this point, then, the Commission had shown by experiment that the most probable way the micrococcus gained entrance to the body was by the alimentary canal, and therefore by some infected food or drink. There was no evidence that contact, inhalation of infective dust, or mosquitoes play any prominent *rôle*. The question arose, What was the infecting food or drink ? The epidemiological facts indicated the water-supply to be free from suspicion. By chance, it was discovered that a large number of goats on the island were excreting the *M. melitensis* in their milk and urine. Further investigation showed that 10 per cent. of the milch goats were yielding an infected milk. Monkeys fed on milk from an infected goat even for one day, almost invariably took the disease. To complete the argument and remove any doubts as to the real interpretation to be placed on the facts, it is noteworthy that, twenty years ago, Malta fever was very common in Gibraltar, but since that time has gradually lessened. In 1883, practically all the goats on the Rock were Maltese, regular shipments of these animals taking place from Malta to Gibraltar. Owing to the withdrawal of grazing passes and the increased cost of shipment, the importation of goats from Malta gradually ceased, and goat-keepers replaced their stock partly by importation and partly by breeding. This disappearance of the Maltese goat has thus synchronised with the disappearance of Malta fever from Gibraltar. Further, attention may be directed to the following accidental experimental infection of man with goat's milk. In 1905, the ss. *Joshua Nicholson* shipped sixty-five goats at Malta for export to America. Their milk was drunk by the captain and crew, with the result that practically every one who drank the milk were struck down with Malta fever. Thirty-two of the sixty goats surviving the voyage were found on arrival in America to give the specific agglutination reaction, while the *M. melitensis* itself was isolated from the milk of several. This epidemic of the disease on board this ship furnishes the clearest proof possible of the connection of Malta fever in man with the Maltese goat.

Prevention.—The epidemiology of Mediterranean fever presents, in view of these facts, little mystery. We can now explain its irregular

seasonal incidence, and the number of cases which occur when there are no mosquitoes and little dust or heat. We can now account for the greater liability of the officer class to attack as compared with the soldier or seaman, since the former consumes much more milk than the latter ; we can explain, also, the isolated epidemics which occur at all seasons in messes and other institutions. Our line of defence is clearly indicated, and resolves itself into the systematic exclusion of goats from the vicinity of houses and barracks, combined with either a total prohibition of the use of goat's milk or the issue of such milk only after sterilisation. The adoption of these preventive measures in the garrison of Malta has already produced most striking results ; they only came into practical use in July 1906, but by the end of the year the number of cases of the disease had dropped to one-tenth of what would have been their normal number. Equally good results have accrued in the naval *personnel*, and there can be little doubt that the adoption of the necessary simple precautions will change Malta from being one of the unhealthiest and most dangerous stations in the British Army to one of the most salubrious.

MEASLES.

Although the original seat or native home of measles is unknown, there can be no doubt that it is a disease of very ancient origin, and in earlier times was often confounded with other maladies, more particularly small-pox and scarlatina. In the present day it is well established throughout Europe, Asia, America, and those parts of Africa of which we have any exact information ; in all these parts it occurs in frequent epidemics. Attempts have been made to show that measles assumes an epidemic or even pan-demic character with a certain amount of regularity, almost amounting to a definite periodicity. Without going so far as to accept this view entirely, it may be admitted that in large communities the disease does tend to occur epidemically at intervals of from two to four years, disappearing between these epidemic outbursts more completely than do some of the other exanthemata. In small communities, especially in rural districts, these intervals are not only less regular but longer.

Influence of Climate and Season.—The practically universal distribution of measles throughout the world indicates that its occurrence is independent of climatic influences ; at the same time the influence of season is everywhere observed. In temperate climates, of 530 epidemics of measles in Europe and North America which Hirsch records, 339 occurred in the colder, against 191 in the warmer months. And the same thing has been observed in the tropics. In this country the effect of season upon urban measles has been studied by Buchan and Mitchell, and by the Registrar-General. The latter, from an analysis of the weekly deaths from measles in London for the sixty years 1841–1900, points out that the weekly curve of deaths shows a double maximum and minimum, the larger maximum falling in November, December, and January, with an extreme excess of 50 per cent. in the fourth week of December, and the smaller in May and June, with an extreme excess of 25 per cent. in the first week of June. The larger minimum falls in August, September, and October, extreme deficit being 45 per cent. below the average in the last week of September ; and the smaller minimum in February and March, the extreme deficit being 30 per cent. below the average in the third week of February. Buchan and Mitchell's analysis of the London death-rates for the thirty years

1845 to 1874 gives very similar results. These facts accord with the conclusions arrived at by both Ballard and Moore that a mean atmospheric temperature above 60° F. was not favourable to the spread of this disease, and that a mean temperature below 42° F. was equally inimical to its prevalence.

Influence of Race, Sex, and Age.—Neither as to liability to attack nor to mortality does racial difference appear to have any effect. Similarly sex and age appear to be without direct influence upon liability to attack, but have some influence upon mortality. On the whole, the mortality is greater among males than females, especially among children under two years of age. About 98 per cent. of all deaths occur among children under ten years of age, 90 per cent. among those under five, 75 per cent. among those under three, and 60 per cent. among those under two (Squire)—the maximum mortality as well as the maximum rate of mortality being in the second year of life.

Mortality.—Of late years the mortality from this disease has shown a tendency to increase. It is much more fatal in the towns than in the country, the ratios per 1000 children living being 3·4 and 1·3; in both areas it levies the highest death-toll among boys. The following table is from the Registrar-General's returns; the figures represent average rates per million living. The rate for 1905 was 324 at all ages, for England and Wales.

	All ages.	Under 5 years.	From 5 to 10 years.
1871–1880	334	2579	208
1881–1890	406	3127	271
1891–1900	414	3247	221

The case mortality of measles is capable of varying within very wide limits, ranging from as little as 2 per cent. in some outbreaks to 40 or 50 per cent. in others. In this connection possibly there are two causes at work, namely, extra intensity of infection and unfavourable surroundings, such as overcrowding, poverty, and fatigue. In an epidemic in Fiji in 1874 all these conditions were operative, together with a probable maximum susceptibility, with the result that the mortality was enormous. The marked influence of insanitary and other unfavourable surroundings upon measles mortality is well shown in military experiences and in civil life, where the death-rate is always higher among the very poor and in overcrowded districts.

Etiology and Infectiveness.—Arguing from analogy, we may assume that the virus of measles is a specific micro-organism. The infection is held to be given off by the breath and mucus, possibly also by desquamating cuticle, though this is less certain. The poison undoubtedly is capable of being air-borne and tends to cling to fomites and to hang about ill-ventilated rooms. There is no evidence of its being conveyed by either water, milk, or food. Infection is probably always acquired by inhalation.

The *incubation* period varies from eight to twenty days, the usual limit being about eleven days. The infective period, or that during which the patient is capable of infecting others, begins with the earliest symptoms. It is probably greatest during the pre-eruptive stage, and while the catarrh and rash are present; there is reason, however, to think that it extend throughout the illness, and even to some extent during convalescence. As a general rule, it may be laid down that infectivity is usually over by the

end of the fourth week, provided all cough and desquamation have ceased. One attack of measles usually confers a lasting *protection* against future attacks; but second attacks sometimes do occur.

Prevention.—This involves isolation of the sick, and arrest of contagious matter by inunction with carbolised vaseline or glycerin; antiseptic inhalations are useful; rags for wiping the eyes and nose should be employed, and afterwards burnt. Clothing and bedding should be disinfected and, under some circumstances, the rooms should be treated similarly.

Theodore Thompson, in his special report on the control of measles, advocated the following preventive measures:—(1) compulsory notification accompanied by prompt and systematic visitation; (2) isolation and disinfection; (3) complete information to be afforded by the sanitary authorities, and all children from an infected house to be rigidly excluded from school; (4) in the case of any exceptional prevalence, general closure of public, elementary, Sunday, and private schools.

MUMPS.

This affection has, at times, all the characters of an epidemic disease, but it is probably endemic in certain localities, especially in large centres of population. At certain seasons, particularly in the spring and autumn months, the number of cases increases rapidly. It is most common in children from ten to fifteen years of age, but the greatest registered mortality is among the very young. Males are, perhaps, more frequently attacked than females, though in institutions and schools the disease has been known to affect over 90 per cent. of all the children. Speaking generally, the mortality from mumps is insignificant, some eighty deaths only being registered annually as due to this disease among the entire population of England and Wales.

The infection of mumps is supposed to be given off by the breath, but as yet no specific organism has been isolated in respect of this infectivity. The period of *incubation* seems most usually to be from a fortnight to three weeks, and is probably seldom much less than twelve days. The period of infectivity seems to extend over at least three weeks. One attack of mumps usually confers immunity, but second attacks are not unknown. At times this disease occurs in close association with measles and diphtheria, and less often with scarlet fever; but whether this apparent relationship is anything more than an accidental one is doubtful. There is no evidence to suggest any connection between mumps and any particular conditions of soil.

Prevention depends upon ordinary measures of isolation and hygiene.

PLAGUE.

The recrudescence in 1894 of the bubonic plague in Canton and Hong Kong, followed by its gradual spread to nearly every country in the world, and coupled with its present extensive prevalence in India, have given this disease considerable importance. The first historical notice of the plague refers to an epidemic in Libya about 98 A.D.; but throughout the Middle Ages occur constant references to its epidemic prevalence, not only in Persia, India, China, Syria, and Asia Minor, but also in Egypt, Arabia, North Africa, Italy, France, England, Germany, and Europe generally. Since 1841 the disease has been unknown in Europe. The whole history of the

disease indicates its tendency to recur in places where it has been once prevalent, and to be carried by trade routes from these centres. A consideration of the events in connection with its previous manifestations enables one to trace its carriage in every case to the affected districts from one or two places where it is, or has been, endemic; these endemic foci being mainly the Euphrates Valley in Central Asia, the Yunnan province in Southern China, the hilly districts of Kumaon and Gurhwal in India, and the Asir plateau in Arabia.

The plague is a specific disease, caused by a specific organism known as the *B. pestis.* The affection occurs in several forms, but the bubonic and the pulmonary appear to be most common. In the bubonic form, usually one group of glands, either the axillary or inguinal, is affected first, and afterwards other groups may become involved, but to a less extent. There is intense inflammatory swelling of the glands, attended by hæmorrhage, and followed by necrosis; true suppuration is rare. Associated with these changes there is great swelling of the spleen and cloudy changes in the kidneys and liver. In the pulmonary form there is the so-called "plague pneumonia" of a broncho-pneumonic type, attended often by hæmorrhage; there may be little or no cough or expectoration. The bacilli are found in enormous numbers in the buboes and in the sputum of the pneumonic form. In man the *incubation* is usually thirty-six hours to five days; the maximum period appears to be ten days.

The specific bacillus has a characteristic form in freshly isolated cultures from acute cases, but is polymorphic and peculiarly liable to undergo involution in artificial media when these are permitted to concentrate by evaporation or are mixed with salt solution to the extent of 3 per cent. It alters, too, in the tissues after degeneration, and after removal from the body or death of the individual, if the examination be delayed some hours. It is seen sometimes as a very short rod, almost like a coccus or a diplococcus, at other times as a short stumpy bacillus with rounded ends. Very often it is found in pairs as a diplococcus, and sometimes in distinct short chains. It stains readily with aniline dyes, but not by Gram's method. The bi-polar staining, which has been much dwelt upon, is by no means a constant phenomenon, and cannot be relied upon for diagnosis. In broth overlaid or not with a bland oil, a characteristic stalactitic form of growth takes place. This is typical of the plague bacillus, but for its demonstration it is essential that the vessel be kept absolutely still. The organism is pathogenic for a wide range of animals, causing in them symptoms and lesions similar to those found in man and rats by natural infection. The criteria for the determination of the bacillus of plague suffice for its identification, but no single test can be relied on. Not only in morphology but in infectivity variations are found. This has been well observed in several outbreaks and is suggestive of the manner of cessation of plague epidemics.

Etiology and Infectivity.—One of the most striking characteristics of plague, once it has become endemic in a locality, is its seasonal prevalence. At or about the same date it yearly reappears, rises, declines and disappears. In populous centres a few cases may occur throughout the year, but in smaller centres the disease disappears commonly entirely for at least six months. The form in which the infection remains latent has been much speculated upon by epidemiologists, and owing to the concurrent prevalence of an apparent epizootic among rats, it was suggested by Simond * and others that it may continue to exist in a chronic form

* Simond: "La Propagation de la Peste," *Ann. de l'Institut Pasteur*, 1898, vol. xii. p. 625.

among these rodents. Kolle * described chronic plague amongst rats in some of his laboratory experiments, but this form of plague among these animals had not been observed in natural conditions. Tidswell failed to observe it in Sydney amongst the large number of examinations made in that city by the Board of Health during the years 1900–1904. Recent work by a special Commission working in India, however, has shown the undoubted existence of chronic plague in rats, which, while running about in apparent health, until examined *post mortem* evinced no signs of ordinary acute plague or other illness.†

These investigations in India point not only to the belief that the epizootic is principally responsible for the spread of plague, but that the outbreak in man is preceded by the extensive development of an epizootic of plague amongst rats. The question at once arises, If this be so, how then does the disease pass from the rat to man ? The necessity for some intermediary between rat and man has been insisted upon on purely epidemiological grounds by Ogata, Simond, and Ashburton Thompson, and all these observers have regarded some suctorial insect, probably the flea, as concerned in transmitting the infection by the act of biting. Nuttall, Ogata, Simond, the German Plague Commission, Tidswell, Zirolia, and Liston have all found the *B. pestis* in the stomach of fleas which had fed upon plague-infected animals, and Liston has brought evidence to show that in certain cases the bacillus multiplies in the stomach of the flea. Many attempts have been made to ascertain experimentally whether fleas can convey the disease—by Simond, Nuttall, Tidswell, Liston, Gauthier and Raybaud, Kolle, Simpson, Kister, and Schumacher, and, no doubt, many others ; but, with the exception of the experiments of Simond, and Gauthier and Raybaud, the attempts to directly accomplish the transmission of plague by fleas have been unsuccessful. The bacillus has also been frequently discovered in the fæces of fleas, and Simond and Zirolia have observed that these insects continuously discharge the contents of their intestine during the act of sucking blood, and the former has suggested that infected fæces discharged in the neighbourhood of the puncture and subsequently rubbed in by scratching, afford another possible means whereby the flea may be instrumental in conveying infection. Even supposing that fleas may be capable of transmitting the disease from rat to rat, the possibility of a similar transmission from rat to man has been vigorously combated by Galli-Valerio on more than one occasion. Galli-Valerio's criticism is based upon his observations that the fleas which he has found upon rats in Europe will not attack man. His criticism is, however, based upon a misunderstanding. The fleas observed by him upon rats in Europe were *Ceratophyllus fasciatus* and *Ctenopsylla musculi*, which, indeed, rarely attack man ; but the common rat flea of India, Australian ports, and Manila, as shown by Liston, Rothschild, and Tidswell, is neither of these species, but *Pulex cheopis*, which has been abundantly shown to attack man readily, especially when its natural hosts are not available. For much information regarding the species of fleas found on rats—*Mus rattus* and *Mus decumanus*—in different parts of the world, we are indebted to Hon. N. C. Rothschild. According to him, *Ceratophyllus fasciatus* is the flea found usually on *Mus decumanus* in Great Britain ; and this is also the case, apparently, throughout Northern and Central Europe. The common house mouse, *Mus musculus*,

* Kolle : "Berichte u. die Thätigkeit in der zu Studien u. Pest," *Zeitsch. f. Hygiene*, vol. xxxvi. p. 411.

† Report on Plague Investigations in India, issued by Advisory Committee appointed by the Secretary of State for India, the Royal Society, and the Lister Institute ; published in *Journal of Hygiene*, 1906, vol. vi. No. 4. This Report gives an extensive bibliography.

occasionally harbours this parasite also, though its usual flea is *Ctenopsylla musculi.*

In other parts of the world by far the commonest rat flea is *Pulex cheopis*, which is identical with the *P. murinus* of Tiraboschi, *P. pallidus* of Tidswell (but not of Taschenberg), and with the *P. philippinensis* of Herzog. It has been found in India, Egypt, Transvaal, Valparaiso, Marseilles (Docks), Philippine Islands, Italy, and once in England. In Europe it is more especially found on ship rats.

In regard to the various questions arising out of the possibility of plague infection being conveyed by *Pulex cheopis*, the Indian investigators make the following conclusions :—

(1) Close contact of plague-infected animals with healthy animals, if fleas are excluded, does not give rise to an epizootic among the latter. As the go-downs were never cleaned out, close contact includes contact with fæces and urine of infected animals, and contact with, and eating of food contaminated with, fæces and urine of infected animals, as well as with pus from open plague ulcers.

(2) Close contact of young, even when suckled by plague-infected mothers, did not give the disease to the former.

(3) If fleas are present, then the epizootic, once started, spreads from animal to animal, the rate of progress being in direct proportion to the number of fleas present.

(4) An epizootic of plague may start without direct contact of healthy animal and infected animal. Thus, in the case of one of the experiments the healthy guinea-pigs were not put in until the last inoculated guinea-pig had died and been removed.

(5) Infection can take place without any contact with contaminated soil. Thus, several guinea-pigs and a monkey placed in wire cages 2 inches above the ground developed plague.

(6) Aerial infection is excluded. Thus, guinea-pigs suspended in a cage 2 feet above the ground, which distance is outside the jumping capability of a rat flea, did not contract the disease, while in the same go-down those animals allowed to run about and those placed 2 inches above the floor became infected.

(7) Plague can be transmitted by the rat flea, not only from guinea-pig to rat, but from rat to guinea-pig. Further, it can also be transmitted from guinea-pig to monkey.

A number of experiments have been made to determine whether the plague bacillus can pass through a series of rats without intermediate culture. A series of twenty-six passages has been successfully carried out without intervention of any artificial culture and without any marked alteration in virulence. This result is clearly of the highest epidemiological importance. From these experiments it was found that the blood of plague-infected rats may contain an enormous number of plague bacilli, even as many as 100,000,000 per c.cm. having been found before death. On the other hand, rats occasionally die from plague with little or no septicæmia. An insect sucking the blood of most rats shortly before death would therefore imbibe a considerable number of bacilli.

While the blood of a rat may have as many as 100,000,000 organisms in a cubic centimetre, the urine of the same animal may have none at all, or at least less than 10 per cubic centimetre. Plague bacilli were discovered in the urine in 29 per cent. of the cases. When the urine does contain plague bacilli they are always present in much fewer numbers than in the blood.

The fæces of rats dead of plague and the blood of which contained

abundant bacteria are not highly infective and would appear to play little part in the spreading of the epizootic.

Many observers have laid stress on the possibility of the soil and mud floors of houses being an important factor in the dissemination of plague. The results of certain experiments made by the Indian Commission on this point may be summarised as follows :—

(1) Floors of cowdung grossly contaminated with *B. pestis* remain infective for forty-eight hours, the infectivity being tested by rubbing scrapings into susceptible animals.

(2) Floors of chunam grossly contaminated with *B. pestis* do not remain infective even for twenty-four hours, the infectivity being tested by rubbing scrapings into susceptible animals.

(3) Floors of cowdung grossly contaminated with *B. pestis* remain infective for twelve hours, but not for twenty-four hours, to susceptible animals which were allowed to run about freely on them.

(4) Floors of chunam grossly contaminated with *B. pestis* remain infective for six hours, but not for twelve hours, the infectivity being tested by allowing susceptible animals to run about freely on them.

Prevention depends upon notification of the disease, isolation of the sick, thorough disinfection of the clothing, personal effects, and houses of infected people, and avoidance of overcrowding. Houses in which dead rats are found should be disinfected. Also inoculation of healthy persons exposed to infection should be resorted to as a prophylactic measure. Every precaution ought to be taken to prevent the entry of rats into cook-houses, cellars, granaries, &c. No dead rat ought to be moved until it has been douched with some solution capable of killing the parasites on the skin.

With regard to the danger of spreading plague by sea, the Indian Plague Commission considered that there was little danger from rats on board ship, and that the suggestion to fumigate the holds of ships so as to destroy rats was both unnecessary and impracticable. Fumigation would have to be done before the cargo was put in the hold, since it would be impossible to fumigate the hold afterwards. We question the wisdom of these conclusions and advocate the systematic destruction of rats on all ships trading with plague-stricken countries. Articles of merchandise were also considered unlikely to be the means of conveying plague from port to port. The incubation of plague is usually less than ten days, and if cases which develop on board ship are at once isolated and the usual precautions taken, it is extremely unlikely that plague will be carried into Europe by persons who have developed plague on the voyage from India. There is, however, always a possibility of plague being introduced by infected clothing, consequently it is of the greatest importance to systematically disinfect the bedding and clothes of crews and lower classes of passengers coming from an infected port. It is probably the fleas in the clothes that are the danger, not the clothes themselves. Rags appear to be the only articles of merchandise which are likely to spread plague; and as it is an extremely difficult matter to disinfect them effectively when they are compressed into bales, the exportation of rags from an infected district should be forbidden. The prevention of plague in India is encompassed by many difficulties. It is almost impossible to obtain notification of plague cases, consequently there will be always foci of disease in the large cities. Systematic corpse inspection has been suggested as a useful measure where notification fails, but the practical difficulties in carrying it out are almost insuperable. Cordons, segregation camps for the healthy, and railway inspections have

all failed to give results at all commensurate with the expense involved in carrying them out, simply because they have been carried out half-heartedly and without system. Other methods must be adopted ; the first of these is the initiation of a definite policy on the part of the Indian Government in combating plague and the provision of a special plague organisation for plague work, equipped with the requisite means for carrying on an anti-plague campaign. Healthy districts should in every circumstance be kept free from plague. This can be effected by a passport system with surveillance and immediate action on the occurrence of a case of plague. In infected areas the only measures likely to succeed are inoculation of contacts and others, evacuation and disinfection of infected houses, and destruction of rats. This latter should be done by poison, by Danysz's virus, and by the encouragement of cats.

Reference has been made to the need of preventive inoculation ; the system elaborated by Haffkine has been extensively tried in India with considerable success. The vaccine is a culture of the plague bacillus in broth killed by exposure to 70° C. for one hour. About 3 c.cs. of the mixture of toxins and dead bacilli are used for each inoculation. As a result of the inoculation there appears to be a diminution in the attack-rates and death-rates in the inoculated as compared with the uninoculated. To quote only one example ; an official report published at Lahore in 1904 contains particulars as to the villages of twelve districts in which the proportion of the inoculated was highest ; the following numbers sum up these results :—Among 639,630 non-inoculated persons 49,443 cases occurred with 29,733 deaths ; among 186,797 inoculated persons there were 3399 cases with 814 deaths. The number of cases was thus reduced to less than one-fourth, the proportion of deaths to cases to less than one-half, and the total death-rate from plague to less than one-tenth of what it was amongst the non-inoculated. During the later operations in the Punjab, a comparison has been made between the immunising effects of microbic bodies from gelatin cultures and those from old broth cultures ; the former showed the proportion of deaths to cases as being 34 per cent., the latter had only 23 per cent., whilst among the non-inoculated the same rate was 60 per cent. From figures quoted by Simpson,* in regard to plague inoculations on a large scale in India, it would appear that the number of cases among those inoculated was reduced by between 52 and 94 per cent., and the number of deaths by between 75 and 100 per cent., as compared to the incidence of attacks and deaths among the non-inoculated inhabitants of the same localities. Haffkine † remarks on the rapidity with which anti-plague inoculation produces its immunising effect, and especially on the possibility of thus arresting the incubation of the disease, or of favourably influencing its progress in persons already infected. He also notes that the white or European race is physiologically less sensitive to plague than are the natives of India, and he surmises that possibly this is the reason why protection conferred by inoculation is higher and more lasting in the European.

* Simpson : "The Croonian Lectures on Plague," *Lancet*, 1907, vol. i. p. 1757, vol. ii. pp. 73 and 142.

† Haffkine : "Inoculation contre la Peste," *Bulletin de l'Institut Pasteur*, October 30, 1906.

PNEUMONIA.

Under this heading we refer to an infectious and not infrequently epidemic form of pneumonia, indifferently spoken of as "epidemic pneumonia," "croupous or fibrinous pneumonia," "pneumonic fever," and "acute lobar pneumonia," occurring as a so-called idiopathic affection. Epidemics of this malady have been described in considerable numbers in England and various other parts of Europe during the last two centuries; the most recent epidemics of importance being those recorded for India (Punjab) in 1875 and 1882, and for this country those occurring at Middlesbrough in 1888, and at Scotter in Lincolnshire in 1890. To these might be added many instances on record of outbreaks of pneumonia which, while remaining limited to a single household or small circle, presented facts strongly suggestive of specific infection.

Influence of Climate and Season.—Assuming that pneumonia, even in its narrowest acceptation of fibrinous or so-called croupous pneumonia, is an anatomical term that includes several inflammatory processes differing from one another in their etiology, the curious prevalence of the malady in both cold and hot countries indicates that climate alone has not much influence upon its prevalence. This, however, is not the case in respect of season. Statistics everywhere show that more persons are attacked in the winter and spring than in the summer and autumn. Seitz's large statistics of 5905 cases in Munich give 32 per cent. in winter, 36·8 per cent. in spring, 15·3 per cent. in summer, and 15·7 per cent. in autumn. So also Hirsch, in an analysis of a large number of cases in various places, states that 29 per cent. were attacked in winter, 34·7 per cent. in spring, 18 per cent. in summer, and 18·3 per cent. in autumn. The seasonal curve of epidemic prevalence coincides very closely with that of sporadic pneumonia mortality, which has its maximum in December, and is high from November to April. From these facts, it is evident that the prevalence of pneumonia—epidemic or otherwise—is associated with the colder months, and a closer analysis shows that in every climate the greatest prevalence of pneumonia occurs at the season of the most rapid and sudden changes of temperature, be it winter or spring, and in some measure varies with the intensity of changes of temperature. Nothing conclusive has been established as regards the influence of rainfall or soil conditions upon pneumonia, though it has been asserted that absence of rain and a low level of the ground water are favourable conditions.

Influence of Race, Sex, and Age.—No race can be said to be exempt, but many coloured races are especially susceptible to it. Longstaff, who critically analysed the deaths from pneumonia, extending over some years, states that, as regards sex, the mortality is greater for males than females at all ages in the proportion of three to two. "The disparity is most marked at ages thirty-five to sixty-five when males suffer more than females, in the proportion of two to one."

The mortality from pneumonia does not vary greatly from year to year. In the year 1905, and in the previous quinquennium likewise, the urban rates very considerably exceeded the rural, but whilst the former rates are falling the latter are rising. In both periods the death-rates from pneumonia were nearly half as high again among males as among females. The age incidence of the several types of pneumonia continues to vary; lobar pneumonia appears to be more especially fatal after the forty-fifth year of life, whereas catarrhal or broncho-pneumonia, whilst also very fatal after the

fifty-fifth year, is enormously more so among young children, to whom it is by far the most fatal form of the malady. The influence of locality on the prevalence of fatal pneumonia may be seen by the following table, which gives the mean annual mortality from that disease per million of the population in town and country, as well as in England and Wales generally, for the ten years 1891–1900 :—

	Urban County Group.	Rural County Group.	England and Wales.
Males . . .	1776	1005	1466
Females . . .	1207	704	1003
Both sexes . . .	1483	849	1227

Etiology.—Of all factors, cold or chill has been thought to be one of the most important, and for years was regarded as the efficient cause of this disease. Undoubtedly pneumonia does follow promptly, sometimes, a sudden chilling or wetting, but in a large majority of cases no such history can be obtained. Exposure to extreme cold or sudden changes of temperature may increase the activity of infection or the susceptibility of the individual, but nothing more. All depressing conditions, such as anxiety, fatigue, poverty, and debility, predispose to pneumonia. Insanitary conditions, especially filth, overcrowding, and want of ventilation, act apparently as powerful, though not indispensable, predisposing causes. Effluvia from drains, sewers, and graveyards have also been held responsible for outbreaks. It is not unusual to find repeated outbreaks occurring in the same buildings, especially casemate barracks and prisons.

The *pneumococcus* of Fränkel is the most constant organism in lobar pneumonia, and is now generally regarded as being the specific agent of the disease. It is identical with the micrococcus which Pasteur and Sternberg found in the saliva of certain individuals, and which produces septicæmia in the rabbit. It occurs occasionally in the nose, the larynx, and the Eustachian tube. According to Netter's observations, it is present in the buccal secretion in 20 per cent. of healthy persons. It persists for months or even years in the saliva of persons who have had pneumonia. The researches of Fränkel, Weichselbaum, Gamaleia, and others show that it is by far the most constant organism in pneumonia, and that it occurs in the secondary processes of the disease, such as pleurisy, endocarditis, pericarditis, and meningitis. In the sputum it may be demonstrated by treating the ordinary cover-glass preparations with glacial acetic acid, and then, without washing off the acid, dropping on aniline oil and gentian-violet, which is to be poured off and renewed two or three times. The organism is seen to be a somewhat elliptical lance-shaped coccus occurring in pairs, hence the term diplococcus by which it is sometimes known. It is usually encapsulated.

According to the modern view, pneumonia is an infective disease caused by this diplococcus, which has its seat of election in, and produces its chief effects on, the lung, and which can, under favouring circumstances, invade other parts of the body. It is a widespread organism, at times present, as before stated, in the buccal secretions of healthy persons. It is not improbable that the various predisposing causes, such as cold, exhaustion, and debility, lower the vitality and render the individual susceptible, thus changing the character of the tissue-soil so that the virus can grow and produce its specific effects.

Several varieties of the pneumococcus have been described, differing from

one another in the symptoms they produce in animals. These varieties differ from one another only in virulence, and by suitable means can be converted into one type. It is important, however, to bear in mind that the pneumococcus in the human subject varies enormously in virulence; this fact partially explains the degrees of severity of the symptoms in different cases. Our knowledge of the toxins of the pneumococcus is still very defective. In artificial cultivations only feeble toxins are produced, and it is thus difficult to study their action carefully. There is, however, sufficient evidence to show that the toxins produce similar constitutional symptoms to those caused by infection with the pneumococcus.

The fact that the pneumococcus is found in many diverse conditions has been urged by some as an argument against the view that it is the cause of pneumonia. We are unable to accept this argument, as it is a general law in pathology that the same micro-organism may produce a different train of symptoms according to the part attacked. The tubercle bacillus causes a different type of disease when it attacks the joints, lungs, brain, or peritoneum. We are just as much justified in speaking of a pneumococcal otitis or a pneumococcal pleurisy as we are of speaking of a tuberculous otitis or a tuberculous pleurisy.

Although the pneumococcus is the cause of croupous pneumonia, yet for the disease to develop there must be other factors than the mere presence of the micro-organism. On this point Washbourn says:—"As to predisposing causes, influenza is the one best known. The other predisposing causes of pneumonia, such as cold and fatigue, are not capable of direct proof. Experimental evidence tells us that exposure to cold and fatigue renders animals susceptible to bacterial infections which in the normal condition they were able to resist. It is interesting to note in this connection that the growth of the pneumococcus outside the body is greatly influenced by very slight changes in the composition of the medium. By analogy we might suppose that slight changes in the composition of the body fluids would be favourable or unfavourable to the growth of the coccus; but this analogy must not be strained, for it would be incorrect to compare too closely the conditions within the body with those occurring in test-tube experiments."

The *incubation* period of pneumonia appears to be short, frequently being about from five to seven days. Both the breath and sputa may be assumed to be infective.

Prevention.—On the supposition that pneumonia is, or may be, infective, the sputa should be received into vessels containing some disinfectant. Soiled handkerchiefs should be well boiled before washing. Care should be taken to avoid chills and exposure to extremes of heat and cold. All dwelling-rooms should be scrupulously well ventilated, and care taken to see that sewer air does not gain access to the habitation.

PUERPERAL PYÆMIA.

Under this term we include the various septic conditions which were included formerly under the indefinite affection styled "puerperal fever." In 1905, in England and Wales, there were 1734 deaths certified under this group, equal to a rate of 1·8 per 1000 births. In the ten years immediately preceding the average proportion had been 2·1 per thousand births.

There is evidence to show that the infection of puerperal pyæmia may come from various septic and decomposition sources other than those of the lying-in room, the chief sources of such infection being the handling of *post-mortem*

materials, and the close attendance upon persons suffering from septic maladies. Allusion has already been made to the fact that erysipelas may have some causal connection with puerperal pyæmia, while less definite evidence is forthcoming that possibly scarlet fever and other infectious diseases may operate in a similar manner. Besides these, various other causes play an indirect but none the less important part in the origin or at least the maintenance of puerperal sepsis. These are overcrowding, insufficient ventilation, drainage defects, accumulations of filth, and want of cleanliness generally. Nowhere have the influences of these conditions been more manifest than in the experiences of lying-in institutions and hospitals whose wards have been allowed to get overcrowded, imperfectly ventilated, and generally dirty. On the other hand, any marked improvement in these respects has always been followed by a marked diminution in puerperal mortality.

Puerperal pyæmia shows similar annual curves to those of rheumatic fever and erysipelas, not only in this country but also on the Continent. This does not necessarily or probably mean identity of virus, but it suggests that the view that want of antiseptic care alone accounts for puerperal septicæmia is not tenable unless it be imagined that in England and in Germany there is in years of excessive mortality from puerperal pyæmia a conspiracy of carelessness. The years of excessive puerperal sepsis are generally years of small rainfall, and the explanation of its epidemic prevalence lies probably in the favouring influence of a dry and warm subsoil on its specific contagium. From this point of view, puerperal fever is essentially a soil disease, having close relationships with erysipelas and other septicæmic diseases. Whether its contagium is alternately parasitic and saprophytic, or each case implies a fresh infection from the soil, is doubtful; but in any case, as based upon analogy with some other diseases, the belief is gaining ground that puerperal fever has wider etiological relations than has been hitherto generally recognised.

RELAPSING FEVER.

Under the names of "famine fever" or "bilious typhoid" this disease was first clearly recognised in 1739 in Ireland, where it still may be said to have its principal focus, at least so far as the United Kingdom is concerned. Epidemics of this affection have not been infrequent in Scotland, and have also occurred in England, Northern Europe, the Levant, India, and elsewhere.

Relapsing fever appears to be entirely independent of soil and largely so of season or climate. It occurs remarkably often in connection with typhus fever, and is apparently closely related to it in etiology, as the two diseases frequently coincide, or one follows the other closely, or isolated cases of the one are observed during the prevalence of the other. This frequent association of the two diseases is mainly to be explained by the fact that their predisposing causes are similar, the diseases themselves being specifically distinct. That the two diseases are distinct is believed mainly upon the following considerations:—(1) that they present marked clinical differences; (2) that one disease does not protect against the other; (3) that the one disease does not give rise to the other; and (4) that the peculiar spirochæte, characteristic of the blood of relapsing fever, is not observed in the blood of typhus patients.

The Mortality from relapsing fever in England and Wales during recent years has been insignificant; the case mortality is low, varying from 2 to 4

per cent. The fatality of relapsing fever is very low during the early years of life, but increases as age advances.

Etiology.—While the predisposing causes of relapsing fever appear to be identical with those of typhus, namely, overcrowding, filth, and starvation, the actual phenomena of the disease are regarded as being essentially dependent upon the presence in the blood of a particular spirochæte, discovered by Obermeyer during the febrile stage, and which disappears from the blood immediately before the end of the febrile stage. The spirochætes are very thin and about 20 μ to 40 μ long, their movement being that of rapidly progressing spirals. Immediately preceding the febrile stage of the disease they appear in the blood, grow more and more numerous during the fever and disappear again completely from the circulation before the fever quite ceases. During the non-febrile stage they probably take refuge in the spleen and bone marrow, where, perhaps, they undergo germination and reproduction. These spirochætes have not as yet been satisfactorily cultivated, but that they are the real causative agents of relapsing fever is proved by the experiments of several observers who have produced typical relapsing fever in apes after injection of blood taken from a patient during the febrile stage and containing the spirochætes.

Whether there is a plurality of species among the spirochætes of relapsing fever is not known; according to Novy and Knapp * the *S. obermeieri* of European and Indian relapsing fever is distinct from the *S. duttoni* of the African disease. These observers further maintain that these spirochætes are bacteria and not protozoa.

Exact data as to the *incubation* period of relapsing fever are wanting, but from what facts are known, it would seem to be from fourteen to twenty-one days. The infective agent is passed from man to man by means of a bug or tick. In the case of the African disease, the invertebrate host appears to be the tick *Ornithodoros moubata*, while in the Indian disease it is either the bed-bug *Cimex lectularius* or *Cimex rotundatus*.

Prevention of relapsing fever is mainly a matter of domestic cleanliness, and freeing the dwelling of verminous parasites. Evacuation and thorough disinfection of all infected premises must be resorted to; disinfection must secure destruction of bugs and ticks. Where huts or houses are of little value, probably burning is the only safe procedure. Other prophylactic measures of the first importance are those which combat poverty, and overcrowding.

RÖTHELN.

In this and other countries there occasionally occur both sporadic and epidemic cases of an ailment having some of the appearances of measles and some of those of scarlet fever, but still not conforming strictly to the clinical and epidemiological characters of either. This malady, seemingly different from measles and from scarlet fever, but having some of the characters of both, is commonly spoken of as "rubeola," "rötheln," or German measles. Many have regarded it as a hybrid of scarlet fever and measles, but the more generally accepted view is that it is an entirely distinct and specific disease.

The disease is undoubtedly infectious, but never very markedly so. The infection is given off probably by the breath and acquired by inhalation.

* Novy and Knapp: "Relapsing Fever and Spirochætes," *Brit. Med. Journal*, 1906, vol. ii. p. 1573.

The period of *incubation* is somewhere about fourteen days, while its period of infectiveness lasts from two to three weeks. The case mortality is low, and there are no very special features in respect of either the influence of age, sex, or race upon its incidence. This malady is of special interest to the public health officer, as the term "German measles" is very loosely employed, and too often is allowed to serve as a cloak to uncertainty in diagnosis. As Goodhart has pointed out, "a doubtful rash makes its appearance, and the medical man, instead of saying he is not certain of its nature, calls it German measles." When we bear in mind that true rötheln is really a very rare disease, it needs little imagination to realise how many cases of either measles or scarlet fever are probably overlooked annually, and permitted to disseminate their specific infection involuntarily but none the less surely throughout the community.

SCARLET FEVER.

We owe the recognition of scarlet fever as a distinct disease to Sydenham, before whose time it was confounded with measles, and occasionally with diphtheria. It is most widely diffused in Northern and Western Europe and in North America, but has failed to establish itself firmly in Africa or any part of Asia, except Syria and some parts of Asia Minor. The disease occurs sporadically from time to time, and then under unknown conditions becomes widespread. Ransome, from a study of the Swedish scarlet fever mortality records, says that "not only a short cycle of four to six years may be traced, but also a long undulation of fifteen or twenty years or more; which may be likened to a vast wave of disease upon which the lesser epidemics show like ripples upon the surface of an ocean swell." Whitelegge, at Nottingham, found that scarlet fever shows a weekly cycle, the notified cases falling to a minimum on Wednesday. This he regards as probably due to the lessened chances of infection through school attendance upon the Sunday. In England scarlet fever is more prevalent in urban than in rural areas, mining and several of the large manufacturing towns being especially affected. In explanation of this it has been suggested that "probably the population in industrial and mining counties live in more than averagely close aggregation, and that the spread of infection is thus facilitated. If, however, this were the true and complete explanation, we should expect the geographical distribution of other infectious diseases to tally with that of scarlet fever." "But this," the Registrar-General remarks, "is not true as regards diphtheria; nor does it seem altogether true as regards measles." Both Longstaff and Barnes have shown the marked difference between the distribution of diphtheria and scarlet fever; in fact, broadly speaking, it may be said that where the latter disease is most prevalent there a particularly low diphtheria rate prevails.

Influence of Climate and Season.—While climatic influences do not appear to play a very prominent part in determining the geographical distribution of this disease, there is evidence that season does influence its prevalence. In England the mortality is at its minimum in March and April, and rises to a maximum in October. In New York, the curve is said to be almost reversed. Whitelegge, by a table based on the notification returns of twelve large English and Scottish towns, has shown that—as was to be expected—the seasonal curve of notified attacks differs little in outline from the mortality curve; but the seasonal range of variation is greater in the attack curve,—in other words, the mortality rises and falls proportionately

less than the cases do, indicating that at the season of the year in which the disease is most prevalent it is least fatal, and *vice versa*.

With respect to the seasonal incidence of this disease, the explanation probably lies in the fact that its prevalence varies according as the period in question corresponds to the interval of school closure for the holidays, or to the period of compulsory attendance at school.

Influence of Age and Sex.—The influence of age and sex upon liability to attack and death by scarlet fever were fully discussed by the Registrar-General in his 49th Annual Report, 1886, and the important conclusions at which he arrived are thus stated :—" (1) The mortality from this disease is at its maximum in the third year of life, and after this diminishes with age, at first slowly, afterwards rapidly. (2) This diminution is due to three contributory causes :—(*a*) the increased proportion in the population at each successive age-period of persons protected by a previous attack ; (*b*) the diminution of liability to infection in successive age-periods of those who are, as yet, unprotected ; (*c*) the diminishing risk in successive age-periods of an attack, should it occur, proving fatal. (3) The liability of the unprotected to infection is small in the first year of life, increases to a maximum in the fifth year or soon after, and then becomes rapidly smaller and smaller with advance of years. (4) The chance that an attack will terminate fatally is highest in infancy, and diminishes rapidly with years to the end of the twenty-fifth year, after which an attack is again somewhat more dangerous. (5) The female sex throughout life, the first year possibly excepted, is more liable to scarlet fever than is the male sex. (6) But the attacks in males, though fewer, are more likely to terminate fatally." These conclusions have been confirmed by the extended experience of recent years.

Mortality.—The following table, compiled from the annual reports of the Registrar-General for England and Wales, shows the mortality from scarlet fever during the last thirty years ; the figures denote rates per million living, after correction for age and sex differences of population. The rate for 1905 was 112 at all ages.

	All ages.	Under 5 years.	5–10 years.	10–15 years.
1871–1880	649	3504	1522	326
1881–1890	312	1667	763	154
1891–1900	158	844	353	81

Even after making allowance for the facts that not only do different outbreaks vary greatly as regards mortality, but that epidemic prevalences tend to occur in cycles, it is justifiable to regard these figures of so long sustained progressive abatement in scarlatinal mortality as an indication that some at least of the means conducing to the spread of this disease are being restricted. The diminution in the mortality may be due to diminished prevalence or diminished virulence ; of the first we cannot speak with certainty, but of the latter there is ample evidence. The marked diminution in the fatality at all age-periods is shown in the table on page 708 relating to the administrative County of London for the ten years 1894–1903.

Etiology and Infectiveness.—The contagion of scarlet fever is probably not developed until the eruption appears, and is particularly to be dreaded during desquamation. No doubt the poison is spread by the fine scaly particles from the skin, but the danger from this source is probably much less than people suppose. Even late in the disease, after all desquamation has apparently ceased, a patient has conveyed the contagion ; in these

cases, however, there is usually to be detected some discharge from, or dried purulent matter attaching to, the nasal and auditory cavities, which probably is more infective than any purely cuticular particles. The poison clings with great persistence to clothing of all kinds and to articles of furniture. In no disease is a greater tenacity displayed. Bedding and clothing which have been put away for months or even for years may, unless thoroughly disinfected, convey contagion. The infection of scarlet fever seems to be given off by the breath, the secretions from the nose, mouth, pharynx, ears, and perhaps kidneys, as well as by the desquamating cuticle. It may apparently cause the disease either by being inhaled or swallowed. There is no evidence of its being conveyed by water, and inasmuch as the disease does not appear to spread in the neighbourhood of fever hospitals, it is doubtful whether the infection can be conveyed any great distance by air currents.

Ages.	Cases Notified.		Deaths.		Case-rate per 1000 living.		Percentage Fatality.	
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
All ages	88,147	96,495	3299	3103	4·2	4·3	3·7	3·2
Under 1 year.	1,450	1,229	205	165	2·7	2·4	14·1	13·4
1–2	3,658	3,437	465	423	7·6	7·2	12·7	12·3
2–3	6,456	6,174	614	566	14·0	13·4	9·5	9·2
3–4	8,471	8,643	576	565	18·8	19·3	6·8	6·5
4–5	9,114	9,476	404	350	20·6	21·5	4·4	3·7
5–10	33,712	38,068	704	729	16·2	18·2	2·1	1·9
10–15	14,423	16,607	150	135	7·2	8·2	1·0	0·8
15–20	5,484	5,447	70	49	2·7	2·4	1·3	0·9
20–25	2,643	3,352	54	58	1·2	1·3	2·0	1·7
25–35	2,027	3,037	36	45	0·5	0·7	1·8	1·5
35–45	511	765	11	9	0·2	0·2	2·2	1·2
45–55	143	188	7	7	0·1	0·1	4·9	3·7
Over 55	55	72	3	4	0·0	0·0	5·5	5·6

Scarlet fever is sometimes disseminated widely by means of an infected milk-supply, and several instances of this mode of diffusion have been reported. Until 1885, all such milk epidemics were believed to be brought about by infection of the milk from a human source. Later investigation, notably by Power and Klein, suggests that human scarlet fever may be produced by milk which owes its infective property to an ailment of the cow. The well-known " Hendon outbreak " constitutes so important and classical an instance of this class of epidemic that it demands some brief reference in detail. In December 1885, a sudden and extensive outbreak of scarlet fever occurred in Marylebone, and was found to be associated with a particular milk-supply obtained from a farm at Hendon. The milk was also distributed in St John's Wood, St. Pancras, Hampstead, and Hendon ; in each of these districts, except the first, scarlet fever became prevalent suddenly early in December. On the 15th the milk sent to Marylebone was returned to the farmer, and some of this was given away to poor people at Hendon on the following days ; from the 20th onwards a number of cases of scarlet fever occurred among those who had drunk the milk. There was, therefore, strong presumptive evidence that the disease was conveyed by the milk. The whole outbreak was investigated by Power and Klein, on behalf of the Local Government Board, with the result that they found the cow itself was the source of infection. Their inquiries indicated that there had been no case of scarlet fever among either the employés or the

neighbours of the dairyman that could reasonably be suspected of having infected the milk. On attention being next directed to the cows, many of them were found to be suffering, or to have recently suffered, from vesicles or ulcers upon the teats and udders. These were readily demonstrated to be infectious, and had been first seen upon a cow which was bought on November 15. The dates of outbreak of scarlet fever in each district being known, it was found that each outbreak was preceded by a few days by the introduction of this affection into the cow-sheds from which the milk-supply of the district was drawn. The early exemption of St. John's Wood was explained by the fact that the disease had not appeared in the small shed from which alone its supply was drawn; but during the inquiry this shed became affected at last, and an outbreak in St. John's Wood immediately followed. All the cows showing any signs of the disease were then isolated, and no further cases of scarlet fever occurred among the consumers of the milk. The symptoms noticed in the cow were chiefly local, but there were bald patches of skin, especially about the tail and back, the epidermis in these patches being scaly and the cutis thickened. There was no pyrexia. The vesicles, which were small, were confined to the teats and udder. They extended, and in two days formed flat irregular ulcers covered with brown scabs. Inoculated upon calves, the matter from these ulcers caused local tenderness and swelling in three days, a scabbed ulcer with vesicular margin in six days, and a further extension during the next few days, followed by healing.

From these ulcers, and from the diseased portions of the viscera of these cows Klein isolated and cultivated a streptococcus which was identical with that which he had obtained from the skin and blood of scarlatina patients. This organism Klein designates as the *Streptococcus scarlatinæ*, and regards it as the microbe of scarlet fever.*

This theory of a bovine scarlet fever is rejected by the veterinary profession and by some medical authorities, but, apart from the facts connected with the Hendon outbreak, evidence is slowly accumulating,† in association with other milk epidemics of scarlet fever, which indicates that there are sources of scarlatinal infection of milk other than those from cases of the human disease. The more recent work of both Gordon ‡ and Kurth § indicates that probably a streptococcus is the causative agent in this disease, but further knowledge is needed. As to the protozoon-like bodies claimed by Mallory || to be the cause of scarlet fever, we have little confirmatory evidence. His observations, however, are worthy of note.

In connection with the so-called return cases of scarlet fever, Thompson investigated the circumstances under which scarlet fever manifested itself anew in certain households to which patients from the Bromley and Beckenham District Council Hospital had returned on recovery from scarlet fever. He found that whilst a distinct proportion of re-invasions was due to the return of hospital patients, it was not improbable that other agencies were in operation, such as excess in that class of household of persons at the ages most susceptible to scarlet fever; season and stage of the epidemic had an

* Klein: "Etiology of Scarlet Fever," *Proc. Roy. Soc. Lond.*, vol xlii.; *also* Report of Med. Off. Loc. Gov. Board. 1886 7: *also see* "Infectious Diseases common to Man and the Lower Animals," *Trans. Epidem. Soc.*, vol. ii., N.S.

† Newsholme: "Scarlet Fever due to Infected Milk," *Public Health*, September 1907, p. 756.

‡ Gordon: "On the Bacteriology of Scarlatina," Rep. Med. Off Loc. Gov. Board, 1900, App. B. 3; 1901, App. B. 7; *also* 1902, App. B. 2.

§ Kurth: *Arbeiten aus dem Kaiserlichen Gesundheitsamts*, 1891, Bd. vii.

|| Mallory: "Protozoon-like Bodies found in Four Cases of Scarlet Fever," *Journ. Med. Research*, 1904, vol. x. No. 4.

important influence, for, with a decadence of the epidemic, the number of return cases sensibly declined. Millard, however, considers that, in the majority of cases, the infection is really carried by the patient leaving hospital. Return cases are most common in the first week and diminish uniformly during the succeeding weeks, until they practically disappear in the sixth week after the return home of the patient. The secretions from the nose and ear appear to contain the virus when infection is unduly prolonged. It is interesting to note that Klein failed to detect the *Streptococcus scarlatinæ* in the desquamating cuticle and urine of advanced cases of scarlet fever ; but he detected it in the throats and nasal discharges of convalescents at intervals of six and nine weeks from the date of attack. Niven has shown that the phenomenon is essentially a hospital one, and that there are good grounds for believing that it is due to recent association of the discharged patient with acute cases. By placing patients in a convalescent ward for fourteen days before their discharge, and systematically disinfecting the skin, nares and auditory canals, " not a single return case occurred in connection with the Manchester patients discharged from the convalescent wards."

The *incubation* period of scarlet fever varies from one to six days, and the period of infectiveness extends from the earliest symptoms to the end of convalescence, necessitating an extension of the period of isolation in most cases to some seven or nine weeks. One attack usually confers immunity throughout life, though second and third attacks occasionally occur. This disease is sometimes found closely associated with diphtheria, while its apparent relationship with a form of puerperal fever has already been referred to elsewhere.

Prevention.—Strict isolation is of the first importance, to which must be added the provision of infectious hospitals and the practice of notification of the disease. Arrest of contagious material from the skin may be secured by inunction with vaseline, oil, or glycerin combined with eucalyptus, carbolic acid, or some other disinfectant. Antiseptic inhalations for the throat and nose are of value. All clothing, bedding, and upholstered furniture must be strictly disinfected ; whether the dwelling-rooms need fumigation is doubtful, as in the majority of cases the infection attaches to the person rather than to walls and floors or ceilings. Milk should be boiled, especially for children. The convalescent person should not be permitted to mix with others until all desquamation has ceased, the process being aided by repeated bathing in warm water to which a little Condy's fluid has been added, and supplemented by thorough cleansing of all parts of the body with soap. The hair and scalp should be cleansed with a mixture of acetic acid, glycerin, and spirit. The greatest care needs to be taken that all sores about the nose and ear passages are healed before patients are allowed to mix with the healthy.

SLEEPING-SICKNESS.

Under a variety of names, this disease has been known since 1803 ; but it is only within the last fifteen years, since Central Africa has been systematically explored, that the symptoms and etiology of the affection have been properly understood. Sleeping-sickness is an endemic disease of different parts of equatorial Africa, characterised by a gradually increasing lethargy, mental and physical degeneration, evening pyrexia, progressive emaciation, and tremors ; after running a more or less chronic course it is almost invariably fatal. Sleeping-sickness has never been known to affect any one who has not, at one time or another, been resident within the endemic area of equatorial Africa.

Neither age, sex, occupation, nor race have any influence on liability or immunity. Any one is liable to acquire sleeping-sickness, but as the negro is more exposed to the cause, he gets it more often than the European. The cause of the disease is the *Trypanosoma gambiense*, first discovered in the cerebro-spinal fluid of cases by Castellani in 1902, and shown by Bruce in 1903 to be conveyed from man to man by the tsetse fly, *Glossina palpalis*. The incubation period of the disease is not known, but it probably is shorter than usually supposed. The chief pathological changes of sleeping-sickness are in the nervous system, where a chronic meningo-encephalitis and meningo-myelitis are set up by the presence of the trypanosomes. The degree of peri-vascular infiltration, so characteristic of the disease, varies and does not correspond to the symptoms, being most marked in the pons, medulla, and cerebellum.

There is no evidence at present that the Glossina palpalis acts otherwise than as a mere vehicular agent; the trypanosomes do not appear to undergo any essential changes in the fly, but are merely conveyed by contamination of, or adherence to, the proboscis, and if the fly be allowed to clean its proboscis by piercing the skin of one person it is no longer infectious to a second.*

Prevention.—The wide distribution of sleeping-sickness in Africa and the rapidity with which it is spreading call for stringent measures being adopted for its prevention. From the nature of things, it follows that the rational form of prophylaxis must be the prevention of entry of infected persons into a district where Glossina palpalis is known to exist and where the disease does not occur. For this purpose Todd † suggests the establishment of medical posts of inspection along the trade routes leading from infected to uninfected districts and the removal of infected persons from posts in uninfected areas to places already infected. Palpation and puncture of the cervical glands affords a ready means of early diagnosis; trypanosomes are easily demonstrated in the fluid drawn from such glands, in infected persons, by a hypodermic syringe. Every negro whose cervical glands are enlarged without obvious cause should be considered to be a case of trypanosomiasis until the contrary is proved.

SMALL-POX.

It is still a disputed point as to the country in which small-pox originated, though the earliest records of its existence are to be found in Hindustan and China, dating many centuries before the Christian era. The *pesta magna* described by Galen, and of which Marcus Aurelius died, is believed to have been small-pox. On the break-up of the Abyssinian army at the siege of Mecca in 570 A.D., owing to the excessive prevalence of the disease among the soldiery, small-pox was gradually disseminated over northern Africa and into Asia Minor. Subsequently it spread to Europe, probably by the Moors, through France and Spain, until by the eighth or ninth century it had reached Saxony, Switzerland, and England. The first accurate account of the affection was given by Rhazes, an Arabian physician, who died about 925 A.D., and whose description is available in Greenhill's translation for the Sydenham Society. It was introduced into the West Indies and

* Minchin, Gray, and Tulloch: "Glossina palpalis in Relation to T. gambiense," *Journ. Roy. Army Med. Corps*, vol. vii. p. 568.

† Todd: "A Means of Checking the Spread of Sleeping Sickness," *Lancet*, 1906, vol. ii. p. 6.

America by the Spaniards early in the sixteenth century. In the seventeenth century a study of the disease was made by Sydenham, who still remains one of the most trustworthy of the earlier authorities on the disease.

In the present day, no part of the world can be said to be exempt from small-pox, or rather from epidemic outbreaks ; while in India, the Sudan, and Central Africa it is so constantly prevalent that those countries may be regarded as endemic foci of the disease. From time to time so-called pandemic extensions occur, involving large areas and characterised by a particularly malignant form of the disease. The last of these was that of 1871–2, which overran Europe and America, and was the cause in these islands of something like 40,000 deaths during the two years.

Influence of Climate and Season.—As Hirsch says, "not many of the acute infective diseases show in their incidence and diffusion so complete an independence of the conditions of climate and soil." Season does seem to have some effect upon the spread of small-pox. In temperate climates, such as England, the mortality curve is above the mean from January to June, and below it from July to December. Taking India as a type of oriental countries, the maximum prevalence is in April and May, that is, in the hot season, but the onset of the rains invariably puts a check to the disease. In Europe and North America the maximum prevalence is usually during late winter and early spring.

Influence of Race, Sex, and Age.—Negroes and all coloured races appear to have a peculiar susceptibility to small-pox, and, moreover, suffer a heavy case mortality. Among aboriginal races the disease is terribly fatal. When it was first introduced into America the Mexicans died by thousands, and among the North American Indians the mortality has been appalling. In respect of *sex*, at most ages the mortality is greatest among males, but in the second and third years of life, and from ten to fifteen years of age, the reverse is, to a slight extent, the case. In relation to *age*, as we shall see presently, the prevalence and mortality of small-pox is essentially a question of vaccination. In pre-vaccination times, about 90 per cent. of the deaths were at ages below five years, the actual maximum being in the second year. In the present day, the deaths under five years, being practically limited to unvaccinated children, constitute about 30 per cent. of the total deaths from small-pox ; and in this age-period the greatest mortality is in the first year. From this point it steadily diminishes until about the fifteenth year, it rises to a second maximum about the twenty-fifth year, and then steadily falls again (M'Vail). The following table, showing annual death-rates from small-pox at varying ages per million living, illustrates this point :—

	Under 5.	5–10.	10–15.	15–25.	25–45.	45 and upwards.
1848–1854	1514	323	91	110	69	24
1855–1864	788	210	68	119	87	36
1865–1874	782	333	142	267	221	87
1875–1884	127	63	46	82	76	34
1885–1894	50	15	11	24	31	19
1895–1904	31	12	7	10	21	17

The decline in the last period is due largely to lowered fatality of the disease, the epidemic type having in the main been very much milder than in the previous groups of years. The first obligatory vaccination law was in 1853, the appointment of vaccination officers was made compulsory in 1871, and various changes in the law, including the introduction of an

exemption clause, was made in the Act of 1898. The table shows how at all ages small-pox has declined since vaccination began.

Infectivity.—Although the exact nature of the specific organism of small-pox has not been conclusively determined, our present knowledge favours the view that it is a parasitic protozoon, probably a sporozoon, and that it is present in the vesicular lymph, the pustules, and the blood.

The *incubation* period of small-pox is practically twelve days, but it may be as short as five and as long as even twenty-one days. Its period of infectiveness lasts quite six weeks in severe cases. Isolation must be maintained for at least three weeks in the mildest cases, and always until every scab has disappeared. After exposure to infection, a quarantine of seventeen days is usually sufficient, but should not be less than a fortnight. Second attacks are rare, except after some years' interval ; third attacks are not unknown.

Occasionally one meets with persons who are entirely insusceptible to the contagion of small-pox ; what is the precise proportion of such insusceptible persons to the general population is very difficult to determine, but taking the mean of many observations, we may put the ratio down as 1 in 20 for adults and 1 in 60 among children.

The disease is disseminated from the sick to the healthy mainly by means of the air, and this power of aerial convection is one of the most striking characteristics of small-pox. It, moreover, can be carried by fomites, as by epithelial *débris*, pieces of clothing, &c. ; similarly, the bodies of persons who have died of the disease, the beds on which they have lain, the furniture of sick-rooms, and all such ordinary means of infection have their share in the diffusion of small-pox. But, hitherto, neither water nor milk has been shown to convey the infection of the disease, though drinking vessels and other domestic utensils, if used by the infected, may serve as the vehicles of conveying the contagion to others.

The well-known investigations of Power, conducted in 1884–5, regarding the influence of the Fulham Small-pox Hospital on the spread of the disease, have shown that the virus can sometimes retain its activity while passing through a quarter of a mile or more of London air. Power showed that, if the district were divided into zones, by means of circles drawn upon the map from the hospital as a centre, with radii of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 mile respectively, and an enumeration made of all the houses in each belt, and also of all houses invaded by small-pox, the proportion of invaded houses diminished as the distance from the hospital increased, and this relation held good in each quadrant of each zone. Since Power's work, numerous instances of alleged hospital influence have occurred and been analysed, notably the case of the small-pox hulks in Long Reach,* the Glasgow hospital at Belvedere, and the more recent circumstances at Gateshead and Liverpool.† The view that, within these hospital one-mile areas, the dwellings nearer to hospital have sustained a heavier incidence from small-pox than those further away, simply as the result of hospital influence, has been vigorously challenged. The alternative theory is that all the phenomena of so-called hospital influence result, in some way or other, from personal communication and traffic. One must admit the question bristles with difficulties, but the more recent cases of hospital influence are not altogether easy to reconcile with this latter view, as the hospitals concerned have been those which

* Thresh : "Small-pox Hospitals and Spread of Infection," *Trans. Epid. Soc.*, 901 2 ; also *idem*, 1904 5.

† Reece : "Liverpool Small-pox and Small-pox Hospitals," Report to Loc. Gov. Board, 1905.

leave little to be desired in the way of organisation, administration and readiness for emergency.

Setting aside all bias, we must agree as to the reality of aerial convection at short distances ; for all infection, other than by inoculation or ingestion, is through the air. We must further recognise that every outbreak of infectious disease in crowded centres affords instances not only of aerial convection, but of personal infection and spread of disease from virulent concealed cases. It is desirable to maintain each of these factors in proper perspective and, in all diseases, to admit and provide for every form of transmission, of which aerial convection is but one, though perhaps playing a more important part in small-pox than in others, and, judging from the analogy of other particulate matter, by no means confined to comparatively short distances. In any case, and whatever opinion may be held as to the merits or the demerits of the air-borne theory, the building of small-pox hospitals in populous districts is probably a thing of the past. For the present, the following instructions of the Local Government Board hold good. That a Local Authority should not contemplate the erection of a small-pox hospital (1) on any site where it would have within a quarter of a mile of it as a centre either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150–200 persons ; (2) on any site where it would have within half a mile of it as a centre a population of 500–600 persons, whether in one or more institutions or in dwelling-houses.

Protection and Vaccination.—Individual protection against an attack of small-pox can be obtained in three ways :—by natural small-pox, by inoculated small-pox, and by vaccination. In former years, protection once acquired was looked upon as permanent and absolute ; but later experience shows that, from whatever cause obtained, the amount of protection varies according to the thoroughness of the protective procedure. Severe small-pox gives more lasting protection than mild small-pox ; small-pox inoculation gives most protection when followed by an eruption ; and a complete, thorough, and multiple vaccination gives more lasting protection than does a vaccination in which only a small single vesicle has been produced.

At the present time, a second attack of small-pox is less frequent than formerly, because, as a result of the practice of vaccination, a first attack of the disease usually comes later in life, so that the protection it affords does not wear off in time to allow readily of a second attack.

Protection from small-pox by deliberate inoculation of the disease, or variolation as it was called, was very generally practised in this country during the last century, and continued until it was made illegal in 1840. The chief objections to it were the danger to life which attended it, the disfigurement which so generally followed, and the fact that the inoculated went about spreading the disease broadcast. The researches and observations of Edward Jenner, between 1768 and 1798, led to the introduction of vaccination, or the inoculation of man with the small-pox of the cow, by which man contracted the affection called *vaccinia*. This vaccinia is, as Jenner always supposed it to be, small-pox of the cow ; but owing to the remarkable change in the cow or calf of small-pox into vaccinia, the poison of human or ordinary small-pox is so weakened as to be unable to cause, except in rare cases, a general eruption, or to spread by atmospheric convection ; in fact, to use the words of M'Vail, the change in the calf from small-pox to vaccinia has the effect of "removing the objectionable and retaining only the valuable part of the original disease." Which is the

ancestor of the other still remains a moot point, but that small-pox and cow-pox are identical was Jenner's firm belief, and the most recent scientific investigations of the subject altogether go to strengthen this view.

Vaccination was introduced by Jenner in 1796, when he claimed for it that, "duly and efficiently performed, it will protect the constitution from subsequent attacks of small-pox as much as that disease itself will. I never expected it would do more, and it will not, I believe, do less." During the earlier part of the present century it gradually superseded inoculation. It was provided gratuitously by the first Vaccination Act of 1840, made compulsory in 1854, and systematically enforced by paid vaccination officers from the time of the pandemic in 1871. Following the introduction of vaccination, there has resulted a remarkable decline in the prevalence of small-pox, not only in England, but in various European countries. This decline, it has been urged, was due, not so much to the use of vaccination as to the decrease of inoculation and to increased attention to sanitation. That the mere decline in the practice of variolation was not the cause of a diminished small-pox prevalence is well shown by the experience of Sweden and Copenhagen, where it so happened inoculation for small-pox was never largely practised ; yet the death-rate from small-pox per million of population was, in Sweden, in the last century, no less than 2050, and now since the introduction of vaccination the death-rate is but 58 per million ; the corresponding figures for Copenhagen are 3128 and 86. As bearing on the question of the influence of sanitation as a factor in the decline of small-pox, it has been pointed out by various writers, principally by M'Vail, that the statistics of all diseases teach that in reference to sanitation each disease has to be considered by itself. Though the removal of fæcal impurities has diminished enteric fever, it has not affected measles. The lessening of overcrowding and personal filth has much lowered the typhus fever rate, but without reducing the diarrhœa rate. Vaccination has diminished small-pox without similarly affecting whooping-cough, and while general cleanliness and purity of water and food are useful against all diseases, yet "the lessening of small-pox cannot be set down to improved drainage any more than can the lessening of enteric fever be set down to vaccination" (M'Vail).

During 1855–64, when vaccination was optional in Scotland, the annual death-rate from small-pox was 340 per million of inhabitants ; but when vaccination was made compulsory the death-rate dropped to 80 per million for the years 1865–90. Upon the same point Edwardes * gives some interesting figures from Sweden, where the small-pox statistics go back to 1774. From that date to the beginning of this century the average annual death-rate was 2008 per million of people. From 1801 to 1815 vaccination was optional, and the death-rate fell to 631. In 1816 vaccination became compulsory in Sweden, and during the period 1816 to 1885 the death-rate has been 173 per million ; while for the last eight years of that period it has been but 41 per million.

Perhaps the strongest argument in favour of the view that it is vaccination and not sanitation which has so reduced the prevalence and mortality of small-pox of late years, is the fact that in pre-vaccination times small-pox was very largely a disease of childhood, while now, owing to infantile vaccination, the main incidence of the disease has been transferred to later periods of life. All statistical evidence shows that, coincidently with the gradual extension of the practice of vaccination, there has been, in the first place,

* Edwardes: *A Concise History of Small-pox and Vaccination in Europe*, London (H. K. Lewis), 1902.

a gradual decline in small-pox mortality at all ages; and, in the second place, that this decline has been exclusively among persons under ten years of age, and most of all among children under five; and thirdly, that after the age of ten years the mortality, so far from having declined, has actually increased—very slightly among persons of from ten to fifteen years of age, but very greatly for persons older than this; and lastly, that the increase has been the greater the more advanced the time of life. This changed incidence of small-pox is one of the most curious and convincing proofs of the efficacy of vaccination, and one which may profitably be studied by a close examination of the facts connected with each and all of the recent small-pox epidemics. No such change of age incidence is to be seen in any of the other zymotic diseases as is found to have taken place with respect to small-pox since the introduction of vaccination. In this connection, the following figures relating to the Glasgow epidemic of 1900–1 are instructive:—

Ages.	Unvaccinated.			Vaccinated.		
	Cases.	Deaths.	Mortality per cent.	Cases.	Deaths.	Mortality per cent.
0–5	54	36	66·6	6	1	16·6
5–10	12	2	16·6	33	—	—
10–15	14	4	28·6	95	2	2·1
15–20	6	2	33·3	133	1	0·7
20–25	6	4	66·6	257	14	5·4
25–35	11	5	45·5	639	51	7·9
35–45	12	4	33·3	353	57	16·1
45–55	7	6	85·7	124	30	24·2
55–65	—	—	—	33	14	42·4
65 and over	—	—	—	15	5	33·3
All ages	122	63	51·6	1688	175	10·4

Similar evidence is forthcoming from a study of the facts relating to the epidemics investigated on behalf of the Royal Commissioners on Vaccination and published in their Report. Taking, also, the six towns referred to in that Report, the total number of children attacked under ten years of age was 2038, of whom 539 died, or 26·4 per cent. Of this total 1449 were said to be unvaccinated, of whom 523 died, or 36 per cent. The remainder, consisting of the vaccinated, amounted to 589, with 16 deaths, or 2·7 per cent. Over ten years of age, the total attacks were 9001 with 744 deaths, or 8·2 per cent. Of these, 870 are classed as unvaccinated, with 299 deaths, or 34·3 per cent., leaving for the vaccinated 8138 attacks with 445 deaths, or 5·4 per cent. Throughout these figures it will be noted that the difference in the fatality rate is much greater between the vaccinated and the unvaccinated under ten years of age than over that age. The explanation is obvious. Over that age vaccination had lost more or less of its protective power.

Much valuable evidence has been collected of late years in regard to the duration of the protection which vaccination gives against small-pox. This evidence indicates that although the susceptibility to the operation of vaccination returns comparatively soon after a primary vaccination, the susceptibility to small-pox returns but slowly; so slowly, in fact, that the power of infantile vaccination against attack by small-pox may be said to remain at least to one-half of its original extent at twenty years of age. On these points the evidence given by Gayton before the Vaccination

Commission (Second Report, page 245) is peculiarly interesting. He found that some 40 per cent. of vaccinated children could be re-vaccinated at the age of from six to ten years ; but of vaccinated children of the same age exposed to the infection of small-pox by residence with cases of the disease, less than 10 per cent. were attacked, though under the same exposure no less than 92 per cent. of unvaccinated children of the same age contracted the disease. If we compare the attack-rates under exposure with the fatality rates among attacked persons in successive age-periods from birth upwards, as shown by the statistics of the great small-pox hospitals, we find that resistance to death by small-pox among the vaccinated outlasts very considerably resistance to attack by small-pox, and also that the inclination to both attack and death by small-pox is much slower in course and much less in ultimate amount in the well vaccinated than in the badly vaccinated.

Ages.	Vaccinated. Good Marks.			Vaccinated. Imperfect Marks.			Said to be Vaccinated. No Marks.			Unvaccinated.		
	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.
0–5	51	0	0·0	182	21	11·5	128	47	36·7	677	383	56·6
0–10	267	2	0·7	714	48	6·7	325	87	26·8	1187	563	47·4
10–20	1045	17	1·6	1976	98	5·0	419	81	19·3	521	160	30·7
20–40	725	37	5·1	1898	258	13·6	420	140	33·5	382	181	47·4
Over 40	48	6	12·5	266	51	19·2	131	44	33·8	79	34	43·0
All ages	2085	62	3	4854	455	9	1295	352	27	2169	938	43

The quality of vaccination, that is, the number, area, and character of the cicatrices, has an important bearing upon the degree and permanence of the protection afforded, as well as upon the case mortality. The preceding analysis of 10,403 cases in the Metropolitan small-pox hospitals, by Gayton, makes this point very clear.

Vaccination is protective against itself as well as against small-pox. Any number of insertions may be made at the time of vaccination ; whether one vesicle is produced or a dozen, the protection is absolute for the time being, but all experience goes to show that the duration of the protection is limited, and is directly proportionate to the number and size of the vesicles produced. For this reason it is desirable to vaccinate in at least four places, and the total area of the cicatrices should not be less than half a square inch. As the protective influence of the primary vaccination fades, a time arrives when re-vaccination becomes possible. Very few persons are insusceptible to re-vaccination after the lapse of ten or twelve years ; many are susceptible within five years, although the primary cicatrices may be good. The course of re-vaccination in the majority of persons is different from that of primary vaccination, being more rapid, and often failing to exhibit some of the typical stages. If, however, the former protection has entirely disappeared, the course of re-vaccination may be identical with that of a primary vaccination.

Re-vaccination renews in all respects the immunity given by primary vaccination. Barry showed that in the Sheffield epidemic the re-vaccinated had a great advantage over the rest. Of 8198 persons re-vaccinated prior to the epidemic, twenty-five were attacked and one died, the attack-rate being therefore 3 per 1000, and the death-rate 0·1. Among 56,233 persons

re-vaccinated during 1887-88, two were doubtfully attacked, and none died.

The incubation of vaccinia being shorter than that of small-pox, it is possible to modify or even entirely prevent an attack of small-pox by vaccination performed some days after infection. This is especially the case with re-vaccination, the incubation of which is often shorter than in primary vaccination. Vaccination, if successfully performed within three days after exposure to infection of small-pox, will prevent the appearance of symptoms, and in all likelihood the attack will be arrested or modified by vaccination if performed as late as the fifth day. The proof of this statement rests upon the observation that attacks of small-pox may and do occur within six days of vaccination in persons who have been many days previously exposed to infection, but the few attacks that occur between six and nine days after successful vaccination are mild, and practically none commence later.

The Vaccination Act of 1898 requires that every child shall be vaccinated within six months of its birth, unless (*a*) death occurs within this period, or (*b*) a medical certificate of postponement is given on the ground of ill-health, or of recent prevalence of infectious disease in the district, or of the condition of the house in which the child resides, or (*c*) the child is attacked by small-pox, or (*d*) three or more unsuccessful attempts at vaccination have been made, in which case insusceptibility is inferred, or (*e*) the parent obtains a magistrate's certificate of exemption. Certificates signed by a qualified medical practitioner must be produced in proof of any exceptions (*a*), (*b*), (*c*), and (*d*). A certain number of children are lost sight of by the vaccination officers, chiefly owing to migration. At the same time, it cannot be denied that wholesale evasion of the law is countenanced by the authorities responsible for the administration of the Vaccination Acts, and that as a result the " proportion remaining unaccounted for " is annually increasing. In 1905, the percentage of children not finally accounted for as regards vaccination, that is, including cases postponed, was 10·7 of the total births throughout the whole of the country; the proportion of cases not finally accounted for in the metropolitan returns for 1905 was 20·6 per cent.; in the provincial returns 9·1 per cent.

The administration of the Vaccination Acts is not in the hands of the Sanitary Authorities, but, subject to the control of the Local Government Board, is entrusted to the Poor Law Guardians. Vaccination may be performed, and the certificate signed by any qualified medical practitioner, but the Guardians must provide for the gratuitous vaccination of all children. For this purpose Public Vaccinators are appointed, and attend at certain convenient vaccination stations at fixed days and hours. Under the Act of 1898 it is no longer incumbent on the parent to take the child to the Public Vaccinator. If the parent so requires, it is the duty of the Public Vaccinator to attend the child at its home. If a child is not vaccinated within four months of its birth, the Public Vaccinator is to visit the home and offer to vaccinate with glycerinated calf-lymph or such other lymph as the Local Government Board may provide. Public Vaccinators are to use only glycerinated calf-lymph or other lymph supplied by the Local Government Board, and must keep registers from which the origin of the lymph used can be identified. The instructions require the greatest care as to cleanliness and sterilisation of instruments used. " The Public Vaccinator must aim at producing four separate good-sized vesicles, or groups of vesicles, not less than half an inch from one another. The total area of vesiculation resulting from the vaccination should not be less than half a square inch."

Vaccination is successful when (*a*) in primary vaccination "the normal vaccine vesicle has been produced," (*b*) in re-vaccination "either vesicles, normal or modified, or papules surrounded by areolæ have resulted." Re-vaccination is entirely optional, but persons over twelve years of age are re-vaccinated gratuitously at the public stations, and if there is immediate danger of small-pox the age-limit is reduced to ten years.

Some people profess to be much opposed to the practice of vaccination, and, in support of this view, allege that (1) vaccination neither prevents nor modifies small-pox; (2) that it gives rise to other diseases; (3) that it is unnecessary, as small-pox is only slightly infectious, and can be prevented by isolation in hospitals. No one who has studied the statistics, nor any one who has read the few facts explained above as to the real nature of the case, can for one moment honestly believe or think that vaccination neither prevents nor modifies small-pox. The truth is, vaccination does both. With regard to the second contention, that vaccination gives rise to other diseases, much untruth has been both written and spoken by prejudiced persons. The facts appear to be that, in a very small percentage of cases, certain diseased conditions have resulted either from, or in consequence of, vaccination having been performed. But when these cases have been closely inquired into, it has been found that grave errors have been committed in the performance of the operation, and that due precautions had not been taken in the choice of the source of the vaccine lymph. Considering the enormous number of vaccinations that have been performed during the past fifty years, it is remarkable how few genuine cases have occurred in which disease has in any way resulted from the procedure. It is probable that with an increased use of vaccine direct from the calf, and the exercise of greater care, the alleged risks of vaccination in this direction will quite disappear. Coming now to the third objection to vaccination, or the statement that it is needless because isolation is a better preventive than it, we find that on this particular allegation there is practically no evidence at all. The available evidence is based upon the experience of Leicester, in which town isolation of the small-pox sick has been very rigidly carried out. But this town is not an instance where isolation has been employed as a *substitute* for vaccination, because the great bulk of the inhabitants of Leicester have been vaccinated at some time or another, with the result that the experience of Leicester really only amounts to an experiment as to the efficacy of isolation, *plus* a certain amount of vaccination. Moreover, the doctors, nurses, and attendants of these isolated small-pox sick are all more or less vaccinated or otherwise protected individuals, which means simply that the patient has around him a cordon of protected or insusceptible people. Surrounded in this manner with persons protected from the disease, it is not remarkable that diffusion or communication of the affection has been small; but where the immediate attendants are not thus protected by either vaccination or re-vaccination, experience shows that isolation alone, as so understood, rapidly results in an overwhelming increase in the numbers of those attacked with the disease, accompanied by an increased severity of the disease type.

There is yet another interesting feature in the Leicester "experiment," and that is the system of "quarantining" for small-pox. In his report upon the outbreak of 1892–93, the Medical Officer of Health explains that by "quarantines" are meant practically persons in small-pox infected houses, for it is clear that such inmates must, more or less, have been exposed to the contagion. He goes on further to say that "such persons may be quarantined (1) in separate hospital wards and reception houses specially provided, a

method, by the way, I do not recommend, whether from the point of view of economy or practicability; or (2) at their own homes, a method I have found satisfactory, both financially and otherwise. The value of quarantining has been well shown during the Leicester epidemic, and I have been able, with comparative ease, by means of my inspectors, to quarantine hundreds of persons at their own homes and with a success that has been gratifying both financially and otherwise. 1261 persons were quarantined, and of these 123 sickened (that is 9·7 per cent.). Each infected house was visited daily by one or other of the inspectors for fourteen to sixteen days. Other persons who had come into contact with small-pox were also watched in the same way. These 'quarantines' were strongly urged—practically compelled—not to go to work for the whole or part of their quarantine period of fourteen to sixteen days, and during that time have been made such monetary allowances as the Committee have thought fit, the sum advanced in each case being no more than sufficient to cover rent and maintenance."

It is clear this is a kind of compulsion which would not be tolerated to any great extent, if it be seriously thought that the system might be made general. In comparison with it, the compulsion of infantile vaccination is a trifling interference with individual liberty.

Prevention.—The most important measures are—(1) Vaccination, (2) Isolation. To these may be added fixation of contagious matter by smearing the skin with olive oil, vaseline, or carbolised glycerin, to prevent its diffusion into the air. All discharges from the nose, mouth, and elsewhere should be received into vessels containing some disinfectant. Rags should be used for wiping the nose, &c., and afterwards burnt. All clothing, bedding, furniture, and dwelling-rooms need to be most scrupulously disinfected. No persons should be allowed near the sick, unless vaccinated; vaccination should be performed upon all individuals occupying the same house in which a case of small-pox has occurred.

[NOTE.—Those desirous of further studying this important subject of vaccination and small-pox should consult M'Vail's article on "Vaccination as a part of Preventive Medicine" in Allbutt and Rolleston's *System of Medicine*, 1906, vol. ii., Part I., p. 767; *also* Copeman on "Vaccination: Its Natural History and Pathology," being the Milroy Lectures, 1899; *also* "Two Hundred and Fifty Years of Small-pox in London," *Journ. Statis. Soc.*, vol. xlv. 1882; *also* Bruce Low's "Report on the Arrangements in Germany for the Isolation of Small-pox Cases," Rep. Med. Off. Loc. Gov. Board, 1903-4; *also* "Translation of German Vaccination Law," *Brit. Med. Journal*, September 23, 1899, p. 789; *also* Millard's Leicester Reports, 1902-4, and *Public Health*, June 1904; *also* Chalmer's Report to the Glasgow Corporation on "Small-pox Epidemic in Glasgow," 1900-2; *also* Report of Royal Commission on Vaccination, 1896.]

TETANUS.

Carle and Rattone were the first to produce typical tetanus in animals, and to show it to be a communicable disease. This they succeeded in doing by inoculating rabbits with pus taken from the ulceration of a human being in whom tetanus had set in; infection of a second animal with the sciatic nerve of the first produced the same symptoms, but inoculations of the blood were negative. Nicolaier made the important discovery that garden earth is often capable of producing, when inoculated into the subcutaneous tissue of the mouse or rabbit, a local suppuration and hæmorrhagic effusion about the seat of inoculation, rapidly followed by typical tetanus and death. At the seat of inoculation fine bristle-shaped bacilli were found; these were often swollen at one end. If the garden earth was previously sterilised by heating it to 110° C., then no effect followed. Rosenbach was the first to demonstrate that the same bacilli exist in the exudation at the place of

infection in human tetanus, and that tetanus was produced and propagated through a series of animals by inoculation of matters taken from near the inoculated place. Hochsinger, Beumer, Peiper, and many others confirmed the existence of these bacilli in tetanus, and even succeeded in producing the disease in animals with them by the aid of foreign bodies, yet these cultures were always in an impure state. The first pure cultivations of the tetanus bacilli were obtained by Kitasato.

The tetanus bacilli are slender bristle-like rods, having circular spores at one end, and possessing but little power of automatic movement. They are strictly anaerobic, and withstand a tolerably high temperature—about 80° C.—without losing their pathogenic power, but growth takes place best at 37° C.

The more exact researches of recent years indicate that the introduction of tetanus bacilli under the skin is followed by the production by them of a chemical virus, which, as it is being produced at the seat of inoculation, is absorbed into the system and has an elective action as a stimulant of the spinal cord ; but the bacilli themselves remain limited to the seat of inoculation, and do not enter the blood or any other tissue. The chemical composition of the poison is not yet known.

Behring and Kitasato have shown that the blood of a rabbit (previously made insusceptible to tetanus) injected into a mouse, otherwise susceptible to tetanus, neutralises in this latter the action of the tetanus bacillus. Tizzoni and Cattoni have gone further than this by showing that the blood-serum of animals, made previously insusceptible, when injected into animals, possesses a decided anti-toxic action. From such blood-serum a tetanus anti-toxin can be prepared, which is effective in neutralising the virus of the tetanus bacilli.

Several cases are on record in which tetanus seems to have been conveyed by the hands or instruments of the surgeon, especially veterinary surgeons. One of the most striking of these is related by Langer, in which the horses castrated by the same *écraseur* died of tetanus, but after boiling the instrument in oil no others died or were affected from its use. Numerous cases are on record of the occurrence of this affection following wounds and injuries in man, the common feature of which has been contamination by dirt, dust, or soil. In view of this fact, that tetanus is produced by a micro-organism to be found in dust, dirt, and adhering to foreign substances, the surgeon will naturally take the greatest care to keep wounds and other injuries free from such contaminating influences. Save in the way of disseminating information on these points among the public at large, tetanus is a malady against which the sanitary officer can do but little. He may, however, point out that the discharges from such wounds should be collected on clean rags or similar materials, which can be either disinfected or burned.

From the frequency with which tetanus is met with among grooms and others much in association with horses, some writers have endeavoured to establish an etiological connection between horses and man in respect of this disease. The doctrine of an equine origin of tetanus has as few facts to support it as has the view that chills, exposures to extremes of heat or cold, and other climatic or meteorological conditions are the cause of the disease. That tetanus is frequent amongst those injured by, or in intimate association with, horses, mules, and other quadrupeds, is probably to be explained by the simple fact that such injuries and associations commonly involve contamination by earth or soil, a medium which we know to be particularly favourable to the specific bacillus.

Prevention.—Extreme cleanliness in regard to all wounds, cuts, or lacerations, especially with a view to avoiding access of soil or any kind of dirt thereto.

TUBERCULOSIS.

This is a diseased condition which occurs in man in a variety of different forms, the most familiar being phthisis, scrofula, lupus, tabes mesenterica, and meningitis. Tuberculosis is not limited to the human race ; it is very common among oxen and cows as a disease known as "grapes" ; it also affects pigs, as well as fowls, rabbits, and guinea-pigs. Though there is every reason to believe that tubercular disease, especially phthisis, has occurred in all ages, there are no data on which to form any estimate as to its relative prevalence in the past in respect of either time or place. In the present day, tuberculosis is certainly more common in some countries than in others ; but this geographical limitation does not mean that the infecting virus is not widespread, but rather that the susceptibility to it is happily far less common. For this reason, the predisposing causes are much more important in this than in any other infective disease.

Influence of Climate and Season.—Speaking generally, tuberculosis is more prevalent in temperate climates, especially in the more populous parts of such countries. Neither hot nor cold climates are exempt, but humidity, especially if the daily range of temperature is high, is frequently associated with the prevalence of pulmonary tuberculosis. Recently, Gordon and Harper * have endeavoured to show a connection between rainy winds and phthisis, but it must be confessed their evidence is not convincing. Cold, and especially Arctic, countries suffer comparatively little as a rule, and the exceptions are mostly explicable by social conditions involving overcrowding and want of ventilation. Other things being equal, elevated and mountainous regions are less affected than lowlands, owing, probably, to the greater dryness and purity of the air and soil, and the deeper and fuller respiratory movements.

As regards the influence of season, in this country deaths from tuberculosis, as evidenced by the phthisis mortality, are most frequent in March and April, and least so in September and October. The seasonal curve of mortality is therefore later than in the ordinary respiratory diseases, and serves really to indicate seasonal conditions accelerating death rather than primarily inducing what is generally a disease of long and uncertain course.

Influence of Race, Sex, and Age.—Jews are said to enjoy a relative immunity from tubercular disease, but, speaking generally, no race is exempt. The coloured races seem to suffer much from phthisis, particularly if they change their natural and primitive habits of life for the conditions associated with a higher civilisation ; this is all the more marked if such changed mode of life is synchronous with migration to a colder and more temperate climate.

Tatham † says that the general teaching of English statistics is as follows :—"In the year 1854 the deaths from all forms of tuberculosis together constituted about a seventh part of the deaths from all causes, which latter were in the proportion of 22·5 per thousand of the population. Half a century later, namely, in 1903, the general death-rate had fallen to 15·4 per thousand, and of these only a ninth part resulted from tuberculosis. In

* Gordon and Harper : "Influence of Rainy Winds on Phthisis," *Brit. Med. Journal*, November 3, 1906.

† Tatham : *System of Medicine*, edited by Allbutt and Rolleston, 1906, vol. i. p. 49.

the decennium 1851–60 the sexes were effected in about equal proportions, but in 1891–1900 the mortality of females did not exceed four-fifths of that of the males." At certain stages of life the incidence of mortality varies enormously. Thus, in the last decennium, among children under five years the proportion of deaths from tuberculous affections did not exceed 7 per cent. of the deaths from all causes, while the proportion at the ages 15 to 35 years amounted to 37 per cent.

Pearson's * studies on the statistical aspects of the inheritance of pulmonary tuberculosis afford some interesting conclusions. He shows from his analysis of the full records of 383 stocks in which cases of pulmonary tuberculosis had occurred that the mean age of onset for men was 29·1 years with a standard deviation of 9·8 years ; for women it was 25·3 years, with a standard deviation of 8·6 years. From his determinations of the correlation between the occurrence of pulmonary tuberculosis in parents and offspring the inference is made that "the diathesis of pulmonary tuberculosis is undoubtedly inherited, and that the intensity of this inheritance is comparable with that found for normal physical characters in man." A study of fraternal correlation leads to the same result. Another result of considerable interest is that "whether we deal with all tuberculous stocks or only with those having no parental history, the elder offspring, especially the first and second, appear subject to tuberculosis at a very much higher rate than the younger members." This does not seem to be due to parental infection, since, in the material analysed, most of the parents had passed the danger zone, fourteenth to the fortieth year, before the onset in the offspring ; further, many of the latter would already have left the home environment. The inference is justifiable that a limitation of family in tuberculous stocks may be an aggravating factor in the national deterioration likely to follow on marriage of the unfit.

Mortality.—It is a matter of common knowledge that tubercular disease occasions an enormous mortality. Owing, however, to the uncertainty which attaches to the actual cause of many of the deaths, especially among children, ascribed to tuberculosis, it is very difficult to ascertain accurately the extent of this mortality. The following table, relating to England and Wales, gives the average death-rates per thousand living at several ages from the principal forms of tuberculosis for the years 1901–5 :—

	All ages.	Under 5 years.	5–	10–	15–	20–	25–	35–	45–	55–	65–	75–
Tuberculosis, all forms	1·64	3·16	0·66	0·58	1·12	1·59	1·99	2·42	2·39	1·91	1·29	0·53
Phthisis	1·14	0·32	0·16	0·29	0·85	1·39	1·82	2·25	2·24	1·76	1·16	0·44
Tuberculous meningitis	0·18	1·08	0·26	0·12	0·08	0·04	0·02	0·02	0·01	0·07	0·00	0·00
Tuberculous peritonitis	0·11	1·06	0·11	0·07	0·05	0·04	0·04	0·04	0·04	0·03	0·02	0·00
Generalised tuberculosis	0·16	0·56	0·08	0·06	0·08	0·07	0·06	0.07	0·06	0·06	0·04	0·01
Other tuberculous affections	0·05	1·14	0·05	0·04	0·06	0·05	0·05	0·04	0·04	0·05	0·07	0·08

This table indicates that among the diseases of the tuberculous group, by far the most destructive is phthisis. The age of maximum mortality from phthisis at the present time is 45–55 years for males and 35–45 years for females. This has not always been so ; in both sexes the age has been postponed. In the decennium 1851–60 the maximum death-rate among females was 4·6 per 1000 and occurred at the age 25–35 ; among males the maximum was maintained from 20–45 years of age, being only at a rate of 4 per 1000 at these ages. It will thus be seen that the relation of phthisis mortality to sex has been reversed in the course of the last fifty years.

* Pearson: "A First Study of the Statistics of Pulmonary Tuberculosis," *Drapers' Company Research Memoirs*, London, 1907.

In the period 1851–60, the deaths from tuberculosis at ages under five averaged 8·5 per cent. of the total deaths from all causes, whilst at ages 15 to 35 years the proportion averaged 46·7 per cent. In the decennium 1891–1900, the averages fell to 6·8 and 37·5 per cent. respectively. During the last forty years there has been a continuous decline in mortality from tuberculosis at every age-period. Although the total death-rate from this disease has fallen by nearly 38 per cent. within the last generation, still considerable changes have taken place in the fatality of its several forms. Whilst, on the one hand, tuberculosis of the lung, the brain and the peritoneum is now less destructive than formerly, on the other hand, there has been a significant increase in the prevalence and fatality of the other manifestations of tuberculosis. In the ten years 1891–1900, out of every hundred deaths from tuberculosis sixty-nine were ascribed to phthisis, eleven each to tuberculous meningitis and tuberculous peritonitis, and nine to other forms of tuberculosis.

Etiology.—Even by the older physicians, tuberculosis was regarded as an infectious disease, but it was not until Koch discovered the tubercle bacillus that this conception of its nature was very generally recognised. The tubercle bacilli in human tubercle are delicate cylindrical rods, measuring from $1 \cdot 5\,\mu$ to $4\,\mu$; many are straight, with rounded ends, but others are slightly curved. When stained, the protoplasm of the bacilli appears segregated into deeply stained, cubical, spherical, or rod-shaped granules; between the granules the sheath is empty, but these empty places are not to be taken for bright spores, nor is it proved that the bright granules are spores. Tubercle bacilli can retain their vitality for a long time outside the body, and this is the chief argument in favour of the bacilli containing spores, though their resisting power is considerably less than that of most spore-bearing bacilli. Dried phthisical sputum has been found to contain virulent bacilli after two months; and tubercle bacilli when completely dried can resist a temperature of 100° C. for an hour, but exposure in the moist condition to 70° C. for the same time is usually fatal. In bovine tubercular matter the bacilli are, as a rule, shorter and thinner, but are in every respect identical with the human species, these minute differences being really differences due to the different soils on which the bacilli were reared.

Tubercle bacilli show definite characters in cultivation. On blood-serum, after ten to fourteen days, these bacilli show themselves in the form of whitish points and patches, resembling dry scales. In broth, the growth is very limited; but by the addition of 6 per cent. of glycerin in meat broth the tubercle bacilli can be brought into rapid and extensive multiplication. The bacilli will not grow below 30° C. or above 42° C.

Koch has shown that by subcutaneous or intra-vascular injection, by inhalation, and by inoculation into the peritoneum or the anterior chamber of the eye, &c., of artificial subcultures removed by many generations from the original source, typical tuberculosis is produced in all animals susceptible to tubercle (guinea-pigs, rabbits, dogs, rats, and mice), and that the tubercular deposits in these experimental animals again contain abundantly the tubercle bacilli; thus, the final and exact proof that the tubercle bacilli are the true cause of the tubercular process is definitely established.

Much controversy has arisen over the question of identity or non-identity of the organisms which produce disease in man and bovines respectively, since Koch's pronouncement (1901) that human tuberculosis cannot be transmitted to cattle and that bovine tuberculosis is not dangerous to man. It has now been proved by the experiments of many observers that cattle can be infected with bacilli derived from a human source; the con-

verse experiments are obviously difficult to carry out, but the epidemiological facts suggest that tuberculosis in infants and young children is due mainly to infection derived from milk.* Hence we are of opinion that all forms of tuberculosis, in man and animals, are produced by the same organism; the more usual modes of infection in man being by way of ingestion and inhalation. Speaking generally, ingestion tuberculosis is a disease of child life, inhalation tuberculosis is a disease of young adult life, although it may occur at all ages. There are a certain number of cases of tubercular infection which present difficulties to explain the precise path of infection, but, whatever the path, it is certain that the bacillus must pass through some portion of either the gastro-intestinal or of the respiratory tract.

Whatever is the path of infection, we must ever regard tuberculosis as an infection, that is, due to a virus which is introduced into the body from without. The bacillus is essentially a parasite and not a saprophyte, having no independent existence outside the body; but there are numerous sources of infection by tuberculous material from both human beings and animals the subjects of the disease. Thus, from mankind there is the sputum from lungs in pulmonary tuberculosis; the fæces or urine when the intestines or urinary tract are the seat of the disease; also the discharges from tuberculous ulcers or fistulæ. Milk from a tuberculous cow is an undoubted source of infection, also the meat or flesh from oxen, pigs, or fowls affected with tuberculosis. Probably the most important of all these, however, are cows' milk and human sputum.

As regards *direct contagion*, it must be confessed that clinical observation is somewhat opposed to the idea that direct infection from another patient is at all common in the etiology of tubercular diseases. Flügge and his pupils have carefully investigated the mode of dissemination of the virus of tubercle, and conclude that infection with dry powdered sputum is undoubtedly possible, but seldom happens, because the very finest dust particles suitable for aerial convection are only derived from perfectly dried sputum, and then in small quantities only. Flügge considers that infection may be caused by the dissemination of minutest bacillus-containing droplets in the act of coughing. Droplets are abundant within 50 centimetres of the mouth, whilst beyond 1½ metres they are rare; hence "continuous association with frequent close approximation as in the case of married couples, nurses, crowded workshops, &c., will greatly increase the likelihood of infection, whereas mere occasional visits and conversation at a distance of not less than a metre reduce the probability almost to nil." Some very striking evidence on this point has been collected from the experiences and after histories of the resident staff and personnel of the Brompton Hospital, which distinctly indicates that phthisis does not commonly spread from a patient to those in intimate contact with him. We ourselves are disposed to think that bovines are the main source of tuberculosis in man, and that the theory of infection by inhalation rests upon imperfect knowledge; we are convinced that this method of contracting the disease is rare.

That milk from cattle, themselves the subjects of tuberculosis, if consumed is a raw state can be the source of infection, is well known. Thus, to quote the conclusions of the present Royal Commission as given in their recent Report:

> There can be no doubt but that in a certain number of cases the tuberculosis occurring in the human subject, especially in children, is the direct result of the introduction into the human body of the bacillus of bovine tuberculosis; and there also can be no doubt

* *See* the Second Interim Report of Royal Commission on Tuberculosis (Human and Bovine). 1907, Part I.

that in the majority at least of these cases the bacillus is introduced through cows' milk. Cows' milk containing bovine tubercle bacilli is clearly a cause of tuberculosis and of fatal tuberculosis in man.

Of the sixty cases of human tuberculosis investigated by us, fourteen of the viruses belonged to group 1—that is to say, contained the bovine bacillus. If, instead of taking all these sixty cases, we confine ourselves to cases of tuberculosis in which the bacilli were apparently introduced into the body by way of the alimentary canal, the proportion of group 1 becomes very much larger. Of the total sixty cases investigated by us, twenty-eight possessed clinical histories indicating that in them the bacillus was introduced through the alimentary canal. Of these, thirteen belong to group 1. Of the nine cases in which cervical glands were studied by us, three, and of the nineteen cases in which the lesions of abdominal tuberculosis were studied by us, ten, belong to group 1.

These facts indicate that a very large proportion of tuberculosis contracted by ingestion is due to tubercle bacilli of bovine source.

A very considerable amount of disease and loss of life, especially among the young, must be attributed to the consumption of cows' milk containing tubercle bacilli. The presence of tubercle bacilli in cows' milk can be detected, though with some difficulty, if the proper means be adopted, and such milk ought never to be used as food. There is far less difficulty in recognising clinically that a cow is distinctly suffering from tuberculosis, in which case she may be yielding tuberculous milk. The milk coming from such a cow ought not to form part of human food, and indeed ought not to be used as food at all.

Our results point clearly to the necessity of measures more stringent than those at present enforced being taken to prevent the sale and the consumption of such milk.

To man the danger of tuberculosis from cattle is a double one, for infection may occur both by the milk and by the flesh or meat. It is now acknowledged generally that the flesh of animals suffering from tuberculosis in a severe form, with fever and emaciation, ought to be absolutely condemned as unfit for human food, and ought not to be given to carnivorous animals, but destroyed, though in America it is allowed to be converted into manure. Differences of opinion arise when we have to deal with animals who have not yet suffered in condition, and in whom the disease is limited to certain viscera. Martin's evidence before the first Royal Commission on Tuberculosis shows that there is danger even in these minor cases, but that it is a danger which may be obviated. He adduced strong evidence that the flesh itself is not infectious, but that it may be rendered so by the process of cutting up and preparing the joints for sale. A knife used for cutting into tuberculous viscera or lymphatic glands will become covered with infective matter, and this may then be smeared on to the joints. That this is a very real danger is further shown by Woodhead's experiments on the effects of cooking. He found that if tuberculous matter were smeared on a piece of meat which was then tightly rolled up, as is done with the rolls of meat sold by butchers, the infective matter was not destroyed by roasting, baking, or boiling, though boiling was more effective than baking, and baking than roasting. There is this further element of danger, that tuberculous matter from a diseased carcass may be conveyed by the butcher's hands and knives to the meat from perfectly healthy animals cut up subsequently in the same place and with the same tools. On these points, the conclusions of the first Commission were: "Provided every part that is the seat of tuberculous matter be avoided and destroyed, and provided care be taken to save from contamination by such matter the actual meat substance of a tuberculous animal, a great deal of meat from animals affected by tuberculosis may be eaten without risk to the consumer. Ordinary processes of cooking applied to meat which has got contaminated on its surface are probably sufficient to destroy the harmful quality. They would not avail to render wholesome any piece of meat that contained tuberculous matter in its deeper parts. The boiling of milk, even for a moment, would probably be sufficient to remove the very dangerous quality of tuberculous milk."

Among other conditions influencing tuberculosis, elevation and *dampness of soil* play an important part; reference to this aspect of the subject has

already been made on page 418. To these predisposing factors must be added *want of sufficient food*, especially want of the fatty elements, and the *breathing of impure air*.

The habitual breathing of air rendered impure by overcrowding or by defective ventilation may, and probably does, act in two ways :—first, indirectly by weakening the resistance of the tissues, and secondly, directly by increasing the chance of infection. Strictly speaking, overcrowding and defective ventilation are not convertible terms ; but in practice we scarcely ever meet one of them apart from the other. Indeed, it is only in very exceptional instances that overcrowding or defective ventilation can be so isolated from other injurious conditions, apart from direct contagion, as to be proved the main cause of tuberculosis.

Prevention.—It is evident from what has been said of the sources of infection that they are all preventable. Of the first importance is the provision of proper ventilation, the avoidance of overcrowding, and in certain trades the provision of an air-supply free from irritating particles. Next is the maintenance of a proper state of nutrition by sufficient and suitable food. Thirdly, the avoidance of chill, and the removal of all predisposed persons from damp soils and climates, combined with plenty of exercise in the open air.

The sputa of phthisical patients should be carefully collected and destroyed. Patients should be urged not to spit about carelessly, but always use a spittoon, or one of the portable cups now on sale. If tubercular sputum is not burnt or boiled it should be disinfected. All handkerchiefs should be well boiled, or, better still, small rags used, which should be burnt immediately afterwards. All tuberculous persons should occupy single beds. Rooms, bedding, and furniture used by the tubercular should be disinfected.

A most important general prophylactic measure relates to the inspection of dairies and slaughter-houses for the detection of tuberculous animals, and the granting of full powers to inspectors to confiscate all suspected animals and carcasses. Slaughtering and dressing should be done under skilled supervision, with the object of securing the removal and destruction of every part of a carcass that contains any tubercle whatever, and also the destruction of the whole carcass in cases where animals are found to have advanced or generalised tuberculosis. All milk should be boiled, especially that to be used by young children. A mother with tuberculosis should not suckle her child.

The foregoing principles of prevention are excellent in their way, but likely to lack efficiency until Local Authorities realise that they have serious responsibilities, and possess already manifold powers in relation to the control of pulmonary tuberculosis. It is incumbent upon all to regard pulmonary phthisis as an infectious disease within the meaning of the Public Health Acts, and it follows that for the effective application of these Acts to pulmonary tuberculosis a system of notification is essential. The segregation of the sick in the same manner as applied to the acute infectious diseases presents many difficulties when we consider the circumstances of many tuberculosis cases. But undoubtedly, where cases of phthisis are treated at home, the Local Authority should insist upon disinfection of the house at frequent intervals during the illness. The same precaution should be taken in respect of workshops and other places where consumptives have been employed. Recognising that risks exist in relation to residence in rooms previously occupied by consumptive persons, the powers possessed by Local Authorities under sections 126 to 129 of the Public Health Act, 1875, should

be enforced in England and Wales, also those under section 7 of the adoptive Infectious Disease Prevention Act, 1890. Similar powers are available in Ireland, both under this Act of 1890, and by the Public Health (Ireland) Act, 1878. In Scotland, the sections 51 and 53 of the Public Health (Scotland) Act, 1897 are similarly applicable.

As regards the vexed questions of isolation and treatment, there can be no doubt that more advantage should be taken of existing powers for the removal of infectious disease cases to hospitals and houses of reception. These powers could and should be adapted in practice to any type of case. In accordance with this view, Local Authorities should recognise the need of providing hospitals and dispensaries for the treatment of the tuberculous poor at every stage of illness. These methods include the establishment of tuberculosis hospitals (sanatoriums) for early cases, hospitals or reception houses for advanced and dying cases, and colonies and homes for convalescent persons, able to work in whole or in part, but still requiring medical supervision. The utility of the sanatorium might be increased by allowing persons whose home conditions are reasonably suitable to attend all day for educative purposes, treatment and *régime*, returning home at night. In the absence of a regular sanatorium, similar benefit might be attained if wards of hospitals for infectious diseases were used for the educative treatment of phthisical patients. The isolation of bedridden patients, when home conditions are such as to preclude the possibility of safe nursing, should be compulsory and a primary duty of all Local Authorities; failing other arrangements, vacant wards in hospitals for infectious diseases might be used for the purpose. These are the main lines on which the administrative control of the most dangerous form of tuberculosis might and should be planned. Nothing has been said of the question of controlling the sale of tuberculous milk; this matter and that of the general control of milk- and food-supplies has been discussed already in Chapter V., but it must never be lost sight of that these administrative problems constitute a prominent and essential detail in all efforts to prevent the dissemination of tuberculosis.*

TYPHUS FEVER.

Historically, this disease is next in importance to the true or Oriental Plague; it is the common pestilence which has accompanied and followed wars from the earliest times. Most probably the plague of Athens, recorded by Thucydides, was what we now call typhus. This name now in use was first applied to a malady or a group of maladies by Sauvages in 1759, and is synonymous with the older terms, "jail fever," "morbus castrensis," "putrid fever," and the modern German term, "typhus exanthematicus" or "Flecktyphus."

Both in Great Britain and Ireland this disease has prevailed with great severity on repeated occasions during the last two hundred years. Since the commencement of the present century there have been epidemics of typhus in 1803, 1817–19, 1826–28, 1836, 1843, 1846–48, 1856, and 1861–70. It must be noted, however, that in some of the earlier epidemics there was a large admixture of cases of relapsing fever, which was not known to be distinct from typhus until 1843, but can even now be recognised by the small mortality which has always attended it. Typhus is more or less

* For an exhaustive review of the "Factors involved in the Control of Pulmonary Tuberculosis," reference should be made to a paper by Newsholme, *Trans. Epidem. Soc. London*, N.S., 1905–6, vol. xxv. p. 31.

endemic in the poor districts of Edinburgh, Glasgow, and Dublin, and was so until recent years in London. As an epidemic it has again and again left its haunts in cities and invaded the whole country. On the Continent and in the United States its course has been chiefly epidemic, and attendant on armies, especially during the miseries of sieges and of retreat. Typhus is rare even as an occasional visitant in the south of Europe, and appears to be almost unknown in India and the tropics generally. It is not uncommon in Northern China.

The disease was introduced into America in 1847 by an infected emigrant ship, and in 1867 by the same means into Australia, but fortunately it has never established itself there. Typhus is unknown among animals; but has been produced by Zülzer in rabbits by injections of blood taken from a sick person when in the height of the disease. These inoculation experiments failed when the blood was drawn from the sick person after the crisis of the disease had passed. Experiments on dogs, made by the same observer, gave negative results.

Influence of Climate and Season.—The disease is essentially one of temperate and cold climates, but by no means unknown in many warm countries, such, for instance, as Mexico, Peru, Persia, North China, and Algeria, where it usually occurs at considerable elevation. In England both the prevalence and mortality of typhus have, on the whole, been greater in the winter and spring than in summer and autumn; but there is a less constant relation to season in respect of this disease than is the case with several of the other epidemic and infective maladies.

Influence of Race, Age, and Sex.—No race is exempt from typhus, but the influence of class and circumstances is shown by the especial incidence of the disease upon the poor and those living under relatively unwholesome conditions.

No age is exempt, but the susceptibility to attack is greatest between the ages of 10 and 20. The mortality from typhus increases from childhood to about 50 years of age, and then declines somewhat. Murchison gives the case mortality at the higher ages as 35·39 in persons between 30 and 40; 43·48 in persons between 40 and 50; 53·87 in those between 50 and 60; and 67·04 per cent. in those over 60. During the first five years of life the fatality is about 6·7 per cent., from 5 to 10 years it falls to 3·6, between 10 and 15 it is not more than 2·3, while from 15 to 20 years of age it rises to about 4·5 per cent.

Although sex appears to have little influence upon liability to attack, the actual fatality is usually somewhat greater for males at all ages taken together than for females. Of 18,268 cases of typhus at all ages admitted into the London Fever Hospital, 18·9 per cent. ended fatally, or a male fatality of 19·6 per cent. of attacks, and a female fatality of 18·2 per cent. Murchison points out that these, being hospital cases, were doubtless above the average as regards severity, and he gives 10 per cent. as a general estimate of typhus fatality; but this naturally varies in different epidemics.

Mortality.—The following figures, taken from the Annual Reports of the Registrar-General, sufficiently indicate the more recent history of typhus fever in England and Wales. In the period 1871–5 the typhus deaths averaged 81·4 per million persons living, in 1876–80 they were 31·2, in 1881–5 the number was 22·8, in 1886–90 they had dropped to 6·6, in 1890–5 to 3·8, in 1896–1900 to 1·4 and in the five years 1901–5 they were 1·4.

Etiology.—No materies morbi has yet been detected, though there can be little doubt of its existence. It cannot be doubted that typhus is distinctly infectious, but recent experiences suggest that the infectiousness is not

so overwhelming as is believed by some. The *incubation* period is variously stated from six to fourteen days, but there appear to be some well-authenticated cases in which it was not more than from two to five days. As regards the period of infectiveness, it is impossible to speak with any certainty. The general opinion is, that the infection is comparatively slight during the first week, but that the disease is most contagious from the end of the first week up to convalescence. This implies that it will probably not be safe to allow a patient to mix with others in less time than a month from the date of attack. In some cases a longer period of isolation may be necessary.

That typhus passes directly to other persons from the sick is established by the clearest possible evidence; and the diffusion of the disease can often be traced from point to point in a town or in a district. Hay * has suggested that the contagion is transmitted from man to man by fleas. The evidence in support of this theory is not very precise, but it explains how typhus is chiefly confined to the poorer and dirtier classes. Certainly the general epidemiological facts as to this disease are not inconsistent with the flea theory, which, if confirmed, will modify our methods of dealing with the disease. The poison, whatever it may be, can certainly attach itself to clothes and bedding, but typhus is not nearly so apt as some of the other contagious exanthemata to be propagated by means of inanimate objects, or of human beings themselves unaffected by it. It has never been shown to be conveyed by water, or by milk or other food.

A second attack of typhus is as rare as one of small-pox, but in exceptional instances the disease appears to confer practically no immunity at all. Such cases, however, are very rare.

Prevention.—To prevent the development of the typhus poison, free ventilation and cleanliness are essential and usually sufficient. Although the prevention of poverty is not always possible, the poor may be supplied with airy, wholesome dwellings, and with the means of maintaining personal cleanliness, such as baths and wash-houses. To prevent the spread of the disease, isolation and disinfection of the sick must be carried out stringently. As the contagion is specially virulent near and about the patient, attendants should avoid exposing themselves (unless protected by a previous attack) unnecessarily to personal contact with the sick or their clothing. All attendants on the infected should wear closely fitting overalls that fasten closely at wrists and neck. The smearing of the neck, wrists, hands and other exposed parts with a solution of eucalyptus oil in olive oil will minimise the risk of bites from vermin. All clothing worn by the patient before admission and during treatment must be carefully disinfected. Bedding and furniture must also be disinfected. The same observations apply to all rooms occupied by the patient either before or during the attack.

WHOOPING-COUGH.

Like so many other epidemic diseases, whooping-cough can be traced to only comparatively recent periods—the earliest notice of it is said to have been by Shenck in 1600. It is a very frequent and widespread disease, and, next to scarlet fever, more fatal than any other in childhood; indeed for infants under one year it is probably the most fatal of all.

Influence of Climate and Season.—Climate does not appear to have much influence upon the prevalence of this disease, except that perhaps

* Hay: "Typhus Fever and Fleas," *Public Health*, September 1907, p. 772.

cold and damp countries are more favourable to it. As regards season, the prevalence of whooping-cough in this country, like the mortality, is greatest about the months of March and April. In this respect its curve of prevalence is almost exactly the reverse of that for scarlet fever. This apparent seasonal prevalence does not probably apply to all countries, as Hirsch, from an analysis of a large number of facts, shows that it is not more apt to be epidemic at one season of the year than another. As regards the effect of weather, Goodhart remarks :—" Atmospheric changes have a most important bearing upon pertussis. It has been repeatedly noticed in the whooping-cough ward at the Evelina Hospital that the children are worse, even when otherwise doing well, when the wind turns cold or suddenly changes ; and it is notorious that the disease runs a much less determined course in summer than in the colder seasons of the year."

Influence of Sex and Age.—Female children are decidedly more liable to be attacked than males. The age at which whooping-cough is most common is between the first year and the eighth. Of the total deaths over 90 per cent. at all ages occur during the first five years of life. Of Goodhart's 352 cases, 62 were under a year old, 212 were between one and four, 65 between four and six, and 13 between six and ten. The mortality among females is greater at all ages than among males. The case mortality is about 2·5 per cent., but varies with age. Although whooping-cough is most prevalent in the earlier years of life, it is sometimes observed in adults up to forty or fifty, or even a still greater age.

Mortality.—In the following table will be found the mortality per million living recorded from this disease in England and Wales during recent years. It shows that the mortality from whooping-cough in this country is still very considerable, in spite of the fact that it has fallen by about 19 per cent. in the course of the last forty years. Like most other infectious diseases of children, whooping-cough is far more prevalent and fatal in urban as compared with rural areas.

Year.	Death-rate.	Year.	Death-rate.	Year.	Death-rate.
1891	468	1896	429	1901	313
1892	454	1897	367	1902	297
1893	342	1898	323	1903	285
1894	410	1899	318	1904	352
1895	315	1900	356	1905	255

Etiology.—Recent observations render it probable that the contagious principle of whooping-cough is an organism analogous to those which produce so many other infective diseases. Bordet and Gengou * claim to have obtained a pure culture of the specific agent, and describe it as a very small bacterium having the same characters in culture as it has in the expectoration ; ovoid in form, staining feebly, especially in the centre. It forms no spores, and is killed by heat at 55° C. The organism can be isolated by employing as a culture medium equal parts of defibrinated human blood and gelatin containing a little glycerin and some decoction of potato. This organism differs from that described by Pfeiffer in (1) growing luxuriantly in media deprived of hæmoglobin ; (2) its colonies are whiter and thicker ; (3) it is larger and more ovoid. From the organisms described by Afanassieff, Czaplewski, Manacatide and Vincenzi, this bacillus differs by being unable to grow on ordinary culture media. The proofs of this organism

* Bordet and Gengou : *Le Scalpel*, September 2, 1906.

described by Bordet and Gengou, being the cause of whooping-cough are not absolutely convincing, but its notable presence only in cases of the disease, and the marked agglutinating effect of serum of children recently recovered from whooping-cough upon the organism are at least highly suggestive that it may be the real causative agent of pertussis.

The disease undoubtedly spreads by infection from case to case, but such infection need not necessarily be direct, as the virus may be carried in clothing, &c. On the other hand, it is said to be one peculiarity of the contagion of whooping-cough that it is far less apt than most other contagia to be transmitted to a distance in an active state. We very rarely find the contagion of whooping-cough conveyed by persons not themselves affected with the disease; but some well-authenticated cases are on record of such having occurred, notably that observed by Bristowe, of a case in which a lady clearly conveyed the contagion of the disease from Sydenham to London upon her dress.

Whooping-cough is peculiarly infective in the early stages, and, like measles, is largely spread by the attendance at schools and other public gatherings of children who are sickening for it, but who have not, so far, manifested the characteristic symptoms. There is no evidence that this disease is ever disseminated by the agency of water, milk, food, or domestic animals; neither does it appear to be in any way connected with soil conditions.

The *incubation* period varies from four to fourteen days, and the period of infectiveness is not less than from six to eight weeks after the disease is declared.

Prevention resolves itself into isolation of the sick person, combined with destruction of all discharges from the air-passages, and the disinfection of clothing and bed linen used by the affected persons. The aerial diffusion of some volatile disinfectant may be a powerful adjunct to these preventive measures, but cannot replace disinfection or destruction of all discharges from the nose, pharynx, and lungs.

YELLOW FEVER.

This is an acute febrile disease of tropical and sub-tropical countries, characterised by jaundice and hæmorrhages, and due to the action of a specific virus. The disease prevails endemically in the West Indies, and in certain sections of the Spanish Main, from whence it occasionally extends, and, under suitable conditions, prevails epidemically in other countries. The first epidemic on record was in 1647, when it appeared in Barbadoes; a destructive pestilence of the same kind occurred at Philadelphia in 1693, and again in 1762, 1793, and 1802. It visited Mauritius in 1815, and Gibraltar in 1804, 1814, and 1828. It is endemic in the island of San Domingo, and more or less frequent throughout the West Indies and the adjacent coasts of Mexico, Guiana, and the southern United States. It first appeared on the Brazilian seaboard in 1849, at Buenos Ayres in 1858, and at Callao in Peru in 1853. Between 1780 and 1820 it repeatedly occurred in Cadiz and other Spanish ports, in 1821 at Barcelona, and later at Marseilles and Leghorn. There was a terrible epidemic in New Orleans in 1878, and in Florida in 1888. Lisbon was affected epidemically in 1857, and Swansea in 1865.

The disease exists also on the west coast of Africa. We may say that there are three main areas of infection:—(1) The focal zone, in which the disease is never absent, including Havana, Vera Cruz, Rio, and other Spanish-

American ports. (2) Perifocal zone or régions of periodic epidemics, including the ports of the tropical Atlantic in America and Africa. (3) The zone of accidental epidemics, between the parallels of 45° N. and 35° S. latitude.

Influence of Climate and Season.—Yellow fever only flourishes in hot climates, and the regions in which it commonly prevails are all situated near the equator. The occurrence of a local epidemic within the temperate zone seems constantly to be associated with an exceptionally sultry state of the weather at the time. In its endemic area, the worst months are generally July, August, and September, or periods of great heat and humidity. Although heat seems essential for the development and prevalence of the disease, it is invariably arrested by frost.

Influence of Race, Sex, and Age.—Although no race can be said to be entirely exempt from yellow fever, there can be no doubt that the negroes are distinctly less susceptible than the whites. Negroes are less liable both to attack and to death in the event of attack. Both attacks and deaths are more numerous among males than females, but this is probably due to greater exposure, and to habits of life. As regards the influence of age, during epidemics in endemic localities, the majority of observed cases occur amongst persons in middle life, because visitors and other unacclimatised persons form a large proportion of the cases, and these people are for the most part adult males. In localities in which yellow fever is not actually endemic, but occurs in occasional epidemics, large numbers of children are attacked, for, unlike the children in endemic areas, they are not acclimatised.

The mortality seems to vary widely in different epidemics, being sometimes as low as 15 per cent., sometimes as high as 75 per cent.

Etiology.—With regard to the origin of yellow fever there have been great differences of opinion, and up to the present time the specific germ of the disease has not been satisfactorily demonstrated. It is probably ultramicroscopic and protozoal in nature, but on this point nothing definite is known. An American Commission, appointed in 1900, investigated yellow fever and proved not only the inoculability of the disease by the blood of yellow fever patients, but also its transmissibility by a mosquito, the *Stegomyia fasciata*; the Commission further proved the non-communicability of the infection, in ordinary circumstances, by bedding or clothing soiled with the dejecta of yellow fever patients. These results have since been confirmed by others. The other more important facts established in regard to yellow fever are that the virus is present in the blood during the first three days of the fever, but not longer; therefore, if a patient can be protected from the bites of mosquitoes during this early stage of his illness, the possibility of his infecting other human beings is remote. The mosquito, fed on yellow fever blood during the infective stage, is not capable of giving rise to the infection by biting a non-immune person, until after the lapse of twelve to fourteen days. The infected mosquito has communicated yellow fever fifty-seven days after contamination, and there is reason to believe that the insect is more virulent after it has been contaminated a considerable time, especially if kept at a temperature of 27° C. This explains the special predilection of the disease for warm climates and seasons.

Marchoux and Simond * appear to have established the transmission of the virus of yellow fever to a new generation of insects; but it is to be noticed that the experimental disease was of a mild type, possibly owing to an attenuation of the virus through the eggs and larvæ of the mosquito. In

* Marchoux and Simond: "La fièvre jaune," *Annales d'Hyg. et de Méd. colon.*, April–June 1903; also *Comptes-rendus Société de Biologie de Paris*, August 4, 1905.

neither the mosquito nor the blood of patients has the virus of yellow fever been discovered ; it apparently belongs to the ultra-microscopic class of parasites, but that it is a parasite may be inferred from the analogy of other infective diseases.

Although the fact of the mosquito playing an important part in the dissemination of this disease is beyond dispute, it has not been proved that this is the only way ; at present no other mode of conveying or acquiring the infection is known.

Among other curious features of yellow fever is the fact that it is a disease of seaports. That it is so is due to the prevalence in these localities of Stegomyia fasciata, to the constant coming and going of susceptible persons, and to the opportunities which these movements afford for the introduction of the malady from infected places. Another peculiarity of yellow fever is, it is a disease of habitations and ships, of the town rather than the country ; these facts are explicable from the circumstance that it is in these places that the stegomyia lurks. A place may be contaminated by the introduction of a yellow fever patient or infected mosquitoes, but neither the patient nor the mosquito can give rise to an epidemic unless the stegomyia is a native of the locality, and even then the evolution, multiplication, and biting virulency of these insects is dependent on the temperature exceeding 26° C.

The influence of residence in a yellow fever locality in lessening susceptibility to the disease is well known, and the duration of this immunity, whether acquired by birth or residence, is in most cases lifelong, but not invariably so. This lessened susceptibility or immunity is acquired apparently as the result of repeated inoculations of the virus in doses insufficient to give rise to a recognisable attack.

The incubation period of yellow fever extends usually from thirty-six hours to five days, but it may be extended to a fortnight.

Prevention.—All permanent and temporary collections of water should be drained, and inequalities of the ground should be filled up so as to afford a ready flowing away of rain-water. When ponds and other collections of water cannot be dealt with in this way, they should be treated with kerosene oil or petroleum to destroy the larvæ of mosquitoes. Cisterns, water-tanks and even gutters should be covered with fine gauze, while such things as broken bottles, cans, barrels, and other receptacles, which are utilised by the stegomyia for breeding, need to be removed. The next point is to prevent the infection of the mosquito ; this can only be done by carefully isolating the patient and protecting him by netting for quite four days ; at the same time the infected house and adjoining premises should be thoroughly disinfected and vigorous fumigation carried out with either formaldehyde or sulphur dioxide in order to destroy mosquitoes. Although bedding and clothing soiled with the discharges of yellow fever patients are apparently harmless, prudence demands that they be disinfected. As illustrative of the value of prophylactic measures on these lines, the experiences of Rio de Janeiro may be quoted. For many years the annual death-roll from yellow fever had averaged 1100; in 1903 prophylactic measures were commenced, the deaths in that year were 928, in 1904 they were 53, and in 1905, 61. Equally good results have been obtained in Havana and New Orleans.*

Ships, when in infected ports, should anchor as far away from the shore as possible and from infected ships. Crews and passengers should avoid the shore as much as they can, and never go ashore after sundown. The infected mosquitoes rarely bite during the day. All tanks, barrels and

* *La Politique Coloniale*, July 13, 1907.

other collections of water on board ships need protection by gauze. Should an outbreak of yellow fever occur on board, the most vigorous fumigation and disinfection should be carried out for the destruction of mosquitoes. If at sea, the vessel should be steered for cold latitudes. Until thoroughly disinfected, a vessel that has had yellow fever on board should not be allowed to approach the shore or other vessels. The hatches and holds of an infected ship should not be opened until sulphur dioxide or some other powerful insecticide has been introduced.

LAW RELATING TO INFECTIOUS DISEASES.

In England and Wales—The Public Health Act, 1875, enacts that, upon the certificate of a Medical Officer of Health or other medical practitioner when the cleansing and disinfecting of any house or part thereof, and of any articles therein, would tend to prevent infectious disease, it is incumbent on the Sanitary Authority to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A daily penalty not exceeding 10*s.* is incurred by default, and the Authority may do what is necessary and recover the costs, or may undertake the duty in the first instance, with the consent of the occupier, at their own cost (section 120). Where the Infectious Diseases (Prevention) Act, 1890, is adopted, the above section is repealed, and the provisions so far modified that the Sanitary Authority may, after twenty-four hours' notice to the owner or occupier, proceed to carry out such disinfection or cleansing, unless within that time he informs the Authority that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the Medical Officer of Health. If he fail to do this within the specified period, it is to be done by the officers of the Sanitary Authority, under the superintendence of the Medical Officer of Health, and the expenses may be recovered. Power of entry between 10 A.M. and 6 P.M. is given for the purposes of this section (sections 5 and 17, Act of 1890).

By section 121 of the Act of 1875, the Sanitary Authority may destroy infected bedding, clothing, or other articles, and give compensation. By section 6 of the adoptive Prevention Act, 1890, the Authority may, by written notice, require, under a penalty of £10, any infected clothing or other articles to be delivered to their officer for disinfection. The Sanitary Authority must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

The Public Health Act, 1875, further enacts that a Sanitary Authority may provide a disinfecting apparatus, and disinfect free of charge (section 122); also provide an ambulance and pay expenses of conveyance of infectious persons to hospital (section 123). Where a hospital is provided within convenient distance, a justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or lodged in a room occupied by more than one family, or is on board any ship or vessel (section 124). The Authority may make regulations for removing to any available hospital, and for keeping there as long as necessary, any persons brought within their district by vessel who are infected with a dangerous infectious disorder (section 125). It is unlawful for any person so suffering to expose himself wilfully, without proper precautions against spreading the disorder, in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously

notifying to the owner, conductor, or driver thereof that he is so suffering; or, being in charge of any person so suffering, to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which have been exposed to infection from any such disorder; but this does not apply to the transmission with proper precautions of articles for the purpose of having them disinfected (section 126). The owner or driver of a public conveyance so used is required under penalty to have the same immediately disinfected; but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him (section 127). Any person who knowingly lets for hire any house or room in which any person has suffered from such disorder, without having it and its contents disinfected to the satisfaction of a medical practitioner as testified by a certificate signed by him, is liable to a penalty not exceeding £20 (section 128). Any person letting or offering for hire any house or part of a house, who, on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such question becomes liable to penalty or imprisonment (section 129).

The above provisions have been supplemented in districts where the Infectious Diseases (Prevention) Act, 1890, has been adopted by the following enactment of that Act now rendered compulsory on all Local Authorities by the Infectious Diseases (Notification) Act, 1899. Section 7 provides that any person who shall cease to occupy any house or room in which any person has, within six weeks, been suffering from any infectious disease, (1) *must* have such house or room, and all articles therein liable to retain infection, disinfected to the satisfaction of a registered medical practitioner, as testified by a certificate signed by him; and (2) *must* give to the owner notice of the previous existence of such disease; and (3) *must not* knowingly, make a false answer when questioned by the owner, or by any person negotiating for the hire of the house or room, as to there having within six weeks previously been therein any person suffering from any infectious disease. Penalties of £10 are provided in each case. Infectious rubbish must not be thrown into any receptacle for refuse without previous disinfection; or in default a daily penalty of 40*s.* (section 13). In any district where these sections are in force the Sanitary Authority must give notice of their provisions to the occupier of any house in which they are aware there is a person suffering from any infectious disease (section 14).

For the further control of the infectious diseases, the provision and utilisation of infectious disease hospitals is a necessity, particularly in crowded areas. This matter is largely dealt with under sections 131 to 133 of the Public Health Act, 1875, and has been discussed at page 477.

It is, of course, of the greatest importance from a sanitary point of view that the dead bodies of persons who have died of infectious diseases should not remain unburied in such a manner as to endanger the health of the survivors. Section 142 of the Public Health Act, 1875, provides that where the dead body of one who has died of any infectious disease is retained in a room in which persons live and sleep, any justice may, on a certificate signed by a medical practitioner, order the body to be removed by the Sanitary Authority to a mortuary, and direct the same to be buried within a time limited by the order; unless the friends of the deceased undertake to so bury the body within the time specified, it is the duty of the Relieving Officer to bury such body at the expense of the poor-rate; but any expenses so incurred may be recovered in a summary manner from any

person legally liable to pay the expenses of the burial. A penalty of £5 attaches to any person obstructing the execution of an order made under this section.

Further provisions in respect of this matter are contained in sections 8 to 11 of the Infectious Diseases (Prevention) Act, 1890, which enact that the body of a person who has died of any infectious disease must not, without a certificate from the Medical Officer of Health, or a registered medical practitioner, be retained for more than forty-eight hours elsewhere than in a mortuary, or in a room not used at the time as a dwelling-place, sleeping-place, or workroom. In such cases, and also where any corpse is retained in a building so as to endanger the health of the inmates, a justice may, upon the application of the Medical Officer of Health, order the body to be removed by the Sanitary Authority to a mortuary, and to be buried within a specified time. Unless the friends undertake to bury, and do bury within a specified time, the Relieving Officer must do so. The body of any person who has died from infectious disease in a hospital must not be removed except for immediate interment or to a mortuary, if the Medical Officer of Health or other practitioner certify that such restriction is desirable for preventing infection. The body of any person who has died from an infectious disease must not be conveyed in any public conveyance, other than a hearse, without due warning to the owner or driver, who must forthwith provide for disinfection.

In cases where there is any suspicion that an epidemic of infectious disease has its origin in any milk-supply of the district, the powers of Sanitary Authorities, under the Contagious Diseases (Animals) Acts, 1886, should not be lost sight of (*see* page 293). In addition to these provisions, Sanitary Authorities of districts in which section 4 of the Infectious Disease (Prevention) Act, 1890, is in force have power to prohibit the supply of milk from suspected dairies. If the Medical Officer of Health has reason to believe that the consumption of milk from any dairy, farm, farmhouse, cowshed, milk-store, milkshop, or other place from which milk is supplied within or without his district, has caused or is likely to cause infectious disease to any person residing in the district, he may, if authorised by a justice having jurisdiction in the place where the dairy is situate, inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by the consumption of the milk, he must report to the Sanitary Authority, forwarding also any report furnished to him by the veterinary surgeon. The Local Authority may then give not less than twenty-four hours' notice to the dairyman to appear before them, and show cause why the supply of the milk in their district should not be prohibited. If, in their opinion, he fails to show such cause, they may order accordingly, and must give notice of the facts to the Sanitary Authority and the County Council of the district in which the dairy is situate, and also to the Local Government Board. The order must be forthwith withdrawn on the Sanitary Authority or the Medical Officer of Health being satisfied that the milk-supply has been changed, or that the cause of infection has been removed. Penalties of £5, and if a continuing offence, of 10s. a day, are provided for contravention of this section of the Act.

The relation of schools to infectious diseases, and the action of Sanitary Authorities in the matter, often presents considerable difficulty. This matter has been discussed already on page 438.

One of the most important and valuable aids to the foregoing provisions has been the *compulsory notification of infectious diseases* under the

Notification Act of 1889, and the Infectious Diseases (Notification) Extension Act, 1899. The Act, which formerly was an adoptive Act, is now compulsory.

The diseases scheduled in this Act are :—Small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus, enteric fever, relapsing fever, continued fever, puerperal fever, but power is given to the Sanitary Authority, with the sanction of the Local Government Board, to include any other infectious disease, such as measles, rötheln, or whooping-cough. Recently, the London County Council have included cerebro-spinal fever among these notifiable diseases, while some other urban authorities have obtained powers to insist upon the notification of pulmonary tuberculosis. The foregoing and scheduled affections are practically those to which also the Infectious Diseases (Prevention) Act, 1890, applies. "Every medical practitioner attending on or called in to visit the patient shall forthwith, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the Medical Officer of Health for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering." The penalty for default is a fine not exceeding 40*s*. Under the same penalty, the householder is compelled to notify, but in a less formal manner, and without receiving any fee. Forms of certificate are supplied to every practitioner practising in the district, and a fee of 2*s*. 6*d*. is paid to him for each certificate regarding a private patient, and 1*s*. for each case in public practice. Though the system of notification is "dual" under the Act, it is so only in theory ; as practically the householder's share in the notification is allowed to lapse as an unnecessary formality, unless there is no doctor in attendance. The Act does not apply to Government buildings, such as barracks, nor to any "hospital" in which persons suffering from an infectious disease are received ; it applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation." The Act gives no power of compulsory removal of patients to hospital, nor even power of entry upon premises for the purpose of making inquiries.

Section 130 of the Public Health Act, 1875, enables the Local Government Board to make regulations for the treatment of persons affected with cholera or any other infectious disease, and for preventing the spread of such diseases as well on the seas, rivers and waters of the United Kingdom, and on the high seas within three miles of the coast thereof, as on land, and may declare by what Sanitary Authorities such regulations shall be enforced and executed. Cholera regulations have been issued under this section, and are discussed not only at page 7, but also in the Appendix, where further reference is made to recent Orders on this subject.

In addition to these regulations, the Local Government Board have power, under section 134 of the Act of 1875, whenever any part of England appears to be threatened with, or is affected by, any formidable infectious disease, to make, and from time to time alter or revoke, regulations for any of the following purposes, namely, for the speedy interment of the dead, for house to house visitation, for the provision of medical aid and accommodation, for the promotion of cleansing, ventilation, and disinfection, and for guarding against the spread of disease ; and may by Order declare all or any of the regulations so made to be in force within the whole or any part of the district of any Sanitary Authority, and to apply to any vessels whether on inland waters or on parts of the sea within the jurisdiction of the Lord High Admiral of the United Kingdom. The Local Authorities are required

to do everything that is necessary to carry out these regulations. The only occasion on which the Board have found it necessary to issue regulations under these sections was in September 1893, to the urban Sanitary Authority of Grimsby and Cleethorpes and the Port Sanitary Authority of Grimsby, when those districts were threatened with a serious invasion of cholera. These orders were revoked on January 8, 1894, on the cessation of the epidemic.

In London the legislative enactments relating to infectious diseases are practically all contained in the Public Health (London) Act, 1891, sections 55 to 87, as both the Infectious Diseases Notification and Prevention Acts are embodied in the London Act of 1891. There are, however, a few modifications necessitated by the fact that the whole of the metropolis has been formed into one asylum district, under managers known as the Metropolitan Asylums Board, who, by the Metropolitan Poor Acts of 1867, 1871, and the Diseases Prevention (Metropolis) Act, 1883, provide asylums for the insane and infirm as well as hospitals for infectious diseases. As regards notification, there is an important difference of procedure in London as compared with England and Wales, namely, that a copy of the certificate must be sent by the Medical Officer of Health, both to the Asylums Board and to the head teacher of the school attended by the patient (if a child), or by any child who is an inmate of the same house as the patient. Besides this, the different Medical Officers of Health receive weekly a full and complete list from the Asylums Board of all notifications in the respective metropolitan districts.

The County Council have power to extend the provisions of the Act as to the notification of infectious disease to diseases not specifically mentioned. The other general provisions as to disinfection, removal of infected persons or dead bodies, and burial of the infective dead, are similar to those already explained under the heading of England and Wales.

Power is also given to the Local Government Board by section 13 of the London County Council (General Powers) Act, 1893, to assign to the Council any duties and powers under epidemic regulations made by them in pursuance of section 134, Public Health Act, 1875, as they deem desirable. In extension of the same, they may substitute the County Council for any Local Authority, on whose default the Council have power to proceed and act under the London Public Health Act of 1891.

In Scotland under section 78, Public Health (Scotland) Act, 1897, the Local Government Board may make regulations for (1) the speedy interment of the dead; (2) house to house visitation; (3) provision of medical aid, accommodation, disinfection, and for guarding against the spread of disease; and (4) for any such matters or things as may appear to them advisable for preventing or mitigating infectious disease. The Local Authority shall superintend and see to the execution of the regulations and shall have power of entry on any premises for the purpose of executing or superintending any regulations issued by the Board (section 82).

Under section 85, regulations made by the Local Government Board provide for their being enforced and executed by the Officers of Customs and by the officers and men employed in the Coast Guard, as well as by other Authorities and Officers—these relate to notification by signal in case of infectious disease; the detention of vessels and of persons on board vessels; the duties to be performed in case of disease by master, pilots, and other persons on board vessels. These regulations shall be subject to the consent of the Admiralty, so far as relates to the Coast Guard; to the Commissioner, H.M. Customs, so far as the Officers of Customs are concerned, and so far as they apply to signals of the Board of Trade.

In Ireland.—The Notification Act, 1889, is in force in only nine rural and seven urban sanitary districts; while the Isolation Hospital Act, 1893, does not extend to Ireland at all. The Infectious Disease (Prevention) Act, 1890, extends to Ireland, but at present has been adopted by five urban and four rural Sanitary Authorities only. The general provisions as to the control of infectious diseases, the compulsory removal of patients to hospital, the disinfection of infected clothing, the removal and burial of the infected dead, and the erection and maintenance of infectious hospitals, as contained in the Public Health (Ireland) Act, 1878, are, with the exception of some minor points, similar to those of the English Act of 1875.

The powers and duties of Port Sanitary Authorities for dealing with infectious diseases has been discussed in Chapter I. at page 6.

CHAPTER XVII

DISINFECTION

THE term *disinfectant*, which has now come into popular use, has unfortunately been employed in several senses. By some it is applied to every agent which can remove impurity from the air; by others to any substance which, besides acting as an air purifier, can also modify chemical action, or restrain putrefaction in any substance, the effluvia from which may contaminate the air; while, by a third party, it is used only to designate the substances which can prevent infectious diseases from spreading, by destroying their specific poisons. This last sense is the most correct, and it is that in which it is solely used here. The mode in which the poisons are destroyed, whether it be by oxidation, deoxidation, or arrest of growth, is a matter of indifference, provided the destruction of the poison is accomplished.

To those substances which arrest the power of propagation of micro-organisms, thereby restraining or preventing decomposition, the general term *antiseptics* should be applied. Those substances which merely oxidise the products of decomposition, and thereby destroy or correct offensive odours, are best described as *deodorants*. In a great many instances the substances which are recommended as disinfectants are little more than deodorants, or, at most, antiseptics or means of checking and delaying putrefaction.

Disinfectants are physical and chemical; the chief physical agent is heat: the chief chemical agents are perchloride of mercury, carbolic acid and the higher phenols, chloride of lime, formic aldehyde, and certain gaseous bodies of strong germicidal power.

In actual practice, disinfection proper is largely aided by the preliminary removal of infection by the scraping and stripping of paper from walls, the washing and sweeping of floors, to say nothing of air perflation, and the washing, beating, shaking, and exposure of clothes. These procedures, excellent in their way, are uncertain and incomplete; the destruction of germs, or true disinfection, is only attainable by either heat or chemical means. For articles of small value, the safest plan is to burn them.

The value of fresh air and sunlight as aids to disinfection must not be overlooked. Direct sunlight, and especially the most highly refrangible, ultra-violet rays of the spectrum, have a powerfully restraining action on the growth of bacteria. Besides these agencies, a comparative purification of the air can be effected by many substances in use for this purpose, but these latter must be regarded as supplemental to, not as substitutes for, true disinfectants.

HEAT AS A DISINFECTANT.

In attempting to estimate the value of heat as a disinfectant we have to bear in mind two questions:—(1) What is the effect upon the colour and texture of fabrics exposed to heat? (2) What is the best form in which to apply heat as a means of disinfection?

On the Liability to Injury of Articles Exposed to Heat.—The possible injuries to fabrics when disinfected by heat are practically the following:—

Scorching or partial decomposition of organic substances by heat. In its earliest stage this manifests itself by change of colour, of texture, and by weakening of strength. Scorching occurs sooner in woollen materials, such as flannels and blankets, than with cotton and linen. Most materials will bear a temperature of 230° F. without much injury, but when this temperature is exceeded, signs of damage soon begin to show. Flannels and blankets exposed to steam at 260° F. for half an hour acquire a distinct yellow tinge, and their tensile strength is somewhat diminished. Exposed to dry heat of 220° F. for four hours, or a moist heat of 228° F. for half an hour, white flannel acquires a slight yellow tinge, but its textile strength is not appreciably impaired. Cotton, linen, and silk will bear a dry temperature of 230° F. for four hours with little alteration, and also moist heat of 250° F. for half an hour with little change, beyond a slight loss of glaze. Feathers become yellowish and brittle after four hours' exposure to steam at 260° F.

Overdrying renders things very brittle; but this injury can be considerably minimised by allowing the materials which have been subjected to dry heat to remain in the air long enough to recover their natural degree of moisture before manipulating them.

Fixing of stains so that they will not wash out.—This property of heat is a very inconvenient one from our present point of view, and is specially marked in the case of albuminous materials coagulable by heat, such as blood or excreta. In order to remove organic stains, the cloth or garment must be steeped in cold water. When the grosser dirt has been removed by soaking and rubbing in cold or tepid water, the articles may be boiled without injury.

Melting of fusible substances, as glue and wax.—This injury does not often occur, and is most commonly met with in attempts to disinfect books and leather goods by heat.

Alterations in colour, gloss, and shrinkage of dyed and finished goods.—Dry heat causes little shrinkage in woven materials. Moist heat, on the other hand, or even wetting without much heat, causes permanent shrinkage in woollen goods, as cloth, flannel, and blankets. To this drawback must be added another, namely, the loss of elasticity and fluffiness, upon which the warmth and softness of woollen materials depend. This elasticity is due to the natural grease of the wool, and is rapidly removed by boiling in water or exposure to moist heat. These materials may be washed in cold water, or exposed to dry heat of moderate temperature without much deterioration, but a frequent repetition of these processes brings about in time a change similar to that effected by boiling water.

Wetting, as when ordinary boiling or hot water is used or steam is employed, is often undesirable in the case of some kinds of goods, for it produces shrinkage and causes colours to run.

Employment of Dry Heat.—At one time dry heat was in very general use as a means of disinfecting clothing; it presents three main disadvantages. The available temperature and the duration of exposure are limited, owing to the tendency to scorch any articles which are exposed: the penetrating power of dry heat is so slow that it is practically impossible to disinfect thoroughly bulky articles such as mattresses and pillows, or fabrics which are folded so as to present any great thickness of material; and lastly, the germicidal effect of dry heat is unreliable owing to the

difficulty of securing an even distribution of a given temperature. The only advantage that can be claimed for dry heat is that leather goods and bound books are not spoiled by it as they are when moist heat is used.

For the carrying out of disinfection by dry heat, the best apparatus is one devised many years ago by Ransom. It is a rectangular chamber of wood and iron, lined with non-conducting material. Hot air mixed with the products of combustion pass into the chamber after being heated by a number of gas-jets, the temperature of this ingoing hot blast being kept constant by an automatic regulator which can be set for any desired temperature. An outlet is provided at the top of the chamber. The best working temperaure is 255° F., this being the highest that can be used for any length of time without risk of singeing cotton goods. When hot air is used, at 255° F., the period of exposure varies from two to eight hours, according to the bulkiness of the articles under disinfection, but penetration of heat is very slow. An automatic device is supplied with this stove to shut off the light and air from the chamber, should the clothing catch fire from overheating. Working with one of these apparatus, Whitelegge obtained the following results; the escaping air had a temperature varying from 245° to 260° F., and a registering maximum thermometer was placed beneath layers of blankets within the apparatus:—

Duration of Exposure.	2 Layers.	4 Layers.	6 Layers.	12 Layers.	18 Layers.
	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
4 hours	220	206	190	162	139
6 „	226	214	208	174	153
8 „	230	221	215	196	182

When moist heat was used, a temperature of 212° F. was obtained beneath sixteen layers of blanket after a maximum exposure of seventeen minutes. This temperature, it is to be noticed, was not reached even after eight hours with dry heat with only twelve layers of blankets.

Employment of Moist Heat.—In its simplest form, this is secured when we soak articles in hot water or submit them to boiling. This procedure has, however, two disadvantages; it is slow, as heat transference occurs solely by conduction and it is liable to damage certain articles by shrinkage, particularly if they contain wool. The most efficient and practical method of employing moist heat is in the form of steam.

The experiments of a number of observers have shown that bacteria and even spores of some bacilli are destroyed by exposure to steam at a temperature of 212° F., for five minutes, or to hot air at a temperature of 250° F., for four hours. Less resistant organisms and free from spores are destroyed by dry heat at 220° F. in an hour. These variations in temperature and exposure, under the two methods, are explicable by the fact that the temperature of sterilisation by heat depends on the original intrinsic dryness of an organism and on the extent to which its proportion of moisture varies during the process. Thus, a spore containing 6 per cent. of moisture should, if its moisture remained constant, resist half an hour's exposure to a little less than 290° F.: if the process, as with dry heat or hot air, removed moisture from the spore, this resistance will be higher; if moisture be added, as with heated water or saturated steam, it will be lower. There is no known limit to the extent to which spores may resist drying, and their albumin may be concentrated to any extent without affecting their vitality. The drier the spore, the less rapidly will moisture penetrate its membrane and

dilute the albumin in the cell. These considerations lead to the conclusion that if disinfection by heat is possible at a temperature below 255° F., which may be taken as the highest that clothes or similar fabrics can stand safely, such disinfection cannot be made many degrees lower with any margin of safety, hence we must exclude any influence tending either to reduce the quantity of water in the organism or to impede the transference of water to the cell contents. An appreciation of these points will explain the greater value of moist heat over dry heat as a means of disinfection.

Steam is saturated or superheated according as it is or is not capable of condensing without requiring increased pressure or reduced temperature. At a higher temperature than that at which it can condense under the existing pressure it is superheated, and it remains so until either the pressure rises to a sufficient extent or the temperature falls. The physical state of superheated steam is accurately expressed by the term "dry steam." Superheat may be produced in steam either by heating the steam without increasing its pressure in proportion, as is done when the steam is contained in a chamber of which the walls are jacketed with hotter steam, or when the steam is generated at atmospheric or other pressure from a saline solution. In either form, superheat prevents the condensation of the steam, which can occur only when the steam has been cooled down to the point of saturation; and until this point is reached it, so far from itself condensing, will take up moisture from surrounding objects until it is saturated, just as unsaturated air will do. Air in steam has a similar effect. The temperature of air-free saturated steam varies directly with the pressure; when the steam is superheated or mixed with air, its pressure ceases to correspond with the temperature. Steam, in the saturated or the superheated condition, may be "confined" in a closed chamber, or it may be used in motion as "current" steam. It may be employed also in the confined or current condition at the ordinary atmospheric pressure, or at a higher pressure than that of the atmosphere.

The effect of saturated steam passing through a disinfector as a current is to sweep out the air which was present originally, and to condense to such extent as may be allowed by its freedom from air and the difference between its temperature and that of surfaces which it meets. The rate and completeness of the air expulsion will vary with the steam velocity. In a disinfector into which it is admitted and remains as confined steam, it mixes more or less completely with the air and condenses much less rapidly than if the air had been expelled. In places in the disinfector where air is trapped or held by objects to be disinfected there may be little or no condensation until the temperature falls; to obviate this, what is termed a "vacuum" is used before admission of the steam. In other cases, the steam is admitted under pressure as a current until the air has been removed and is then used confined, a process which quickens the removal of the air and economises the steam.

No matter what kind of apparatus is used, the effect of steam upon porous objects is intended to be the same. The steam on meeting a colder surface will condense to such an extent as its superheat and intermingled air, if such conditions exist, and the presence of grease on the articles to be disinfected may allow. In condensing, the steam yields its "latent heat," which is sufficient to raise over five times its own weight of water or some fifteen times its weight of wool from 0° to 100° C. At the same time it shrinks to about $\frac{1}{1600}$th of its original volume, and fresh steam is sucked into the space so left vacant until in its turn it condenses on the next surface, evolving latent heat as before. In this way, steam pene-

trates finally the porous objects and raises them to its own temperature. It is to this succession of condensations that steam owes its characteristic power and rapidity of penetration, and anything which interferes with these condensations delays and may prevent the penetration of the heat.

It will be readily understood that any apparatus for disinfection by heat should have doors at opposite ends, one for the reception of infected goods, and the other for the removal of the goods after disinfection ; each of these doors should open into entirely separate rooms with separate entrances. One of these rooms should be reserved strictly for infected and the other for disinfected goods, and no articles should be allowed to enter the latter room except through the stove or apparatus. Each door must be air- and steam-tight and fastened by strong screw-clamps. The articles to be disinfected are placed in trays or suspended from sliding racks, which are easily pushed in or withdrawn from the disinfector.

A variety of apparatus have, from time to time, been invented for the

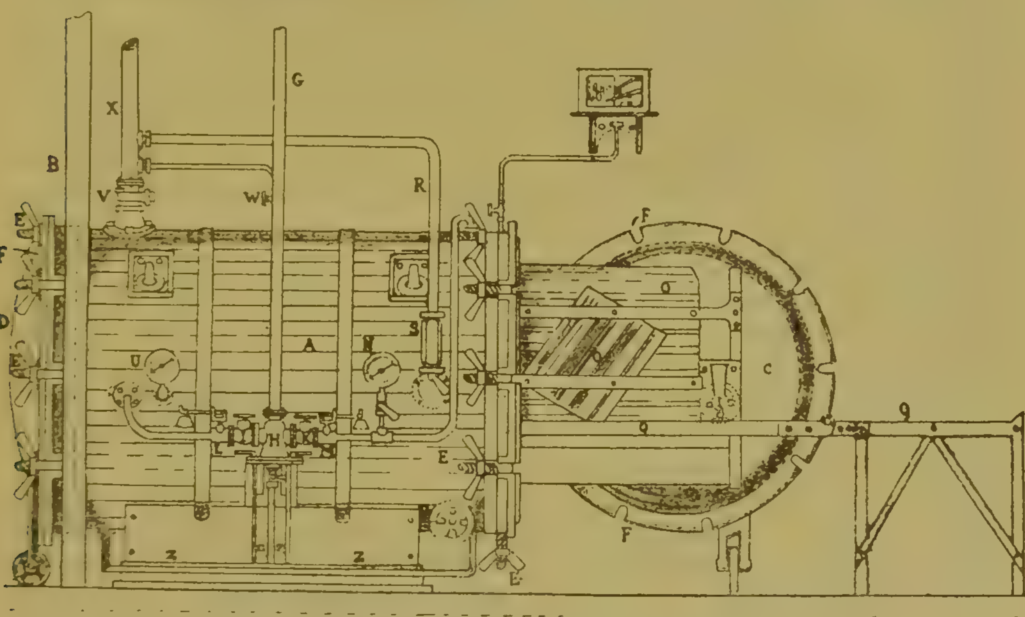


Fig. 156.—Equifex Disinfecting Stove.

application of steam to disinfection ; these divide themselves into two main groups, namely, high-pressure disinfectors using confined steam, and low-pressure disinfectors using current steam. A high-pressure apparatus usually derives its steam from a separate boiler, which may also provide steam for driving laundry or other machinery. Low-pressure disinfectors derive their steam from a boiler which forms an integral part of the machine. This boiler usually takes the form of a jacket round the disinfector, and in the jacket the water is heated by a furnace placed below the apparatus.

A machine, in whatever form the steam is used, must comply with the following conditions : (*a*) there must be uniform distribution of heat in the interior ; (*b*) a constant temperature must be maintained during the process of disinfection ; (*c*) there must be means of ascertaining the temperature of the interior at any given moment. These conditions are best fulfilled by the machines which employ confined saturated steam under pressure ; the Equifex stove may be taken as the type of this class.

"The disinfecting chamber is a wrought-iron cylinder without a jacket or other means of superheating the steam, but lagged with wood and coated

with a non-conducting composition, so as to reduce cooling through the walls of the chamber. A row of steam-tubes runs longitudinally inside the stove at the bottom for warming the stove before and during disinfection, and for heating the air which is used in the subsequent drying of thick objects. The steam is led to the stove by a pipe G from the boiler, and, after traversing a separator H, passes through the reducing-valves I K and safety-valves L M to the stove and tubes respectively. When the desired pressure is reached in the tubes, as shown by the gauge N, steam begins to escape through the safety-valve M, and the attendant then regulates the pressure by the reducing-valve K. The stove, having thus been warmed, is charged with the objects to be disinfected. The door is then closed and the valve I is opened, allowing steam to pass through the safety-valve L into the body of the stove. The steam enters the stove through an internal sparge-pipe fitted longitudinally inside it towards the top, and furnished throughout its length with a screen to assist in the thorough projection of the steam to all parts of the stove. The steam is at first allowed to escape through the air discharge-pipe R, and carries with it the air from the stove. When the air is ejected the mercury in the thermometer S will rapidly rise to 195° to 205° F., at which point the valve T controlling the pipe R is closed. The steam continues to enter the stove through the valve I till it reaches a pressure of 10 lb. per square inch ; the attendant then regulates the pressure to this point by the reducing-valve I. A film of water is formed throughout the pores of the object under a pressure sufficient to keep it from evaporating. Advantage is taken of this fact to get rid of the air secreted originally in the pores of the object by shutting off steam about every five minutes and opening the sluice-valve V. The sudden reduction of pressure causes the water condensed in the pores to expand into steam and sweep out before it the air from the pores. To assist this process the stove is fitted with a pneumatic exhaust ; a jet of steam is allowed, by means of the valve W, to pass up an aspirator or ejector fitted in the steam discharge-pipe X, so automatically sucking out both the steam and the air ejected from the pores, and producing a partial vacuum, under which the vaporisation of the steam and the ejection of the air is completed. With objects of ordinary thickness disinfection is complete in fifteen to seventeen minutes. Steam is then let off as before ; and on the door being opened all objects, such as blankets, clothes, &c., are taken out and shaken, when they will be found to be perfectly dry. The thicker objects, such as mattresses, are replaced in the stove, which is again closed and the air-valve Y is opened. The aspiration due to the steam-jet operating in the aspirator or ejector draws in air through this valve. Such air is heated in its passage over the lower steam-pipes, and, in passing over the mattresses, &c., sweeps away the steam, which is continuously extracted from them until they are perfectly dry. This process for ordinary mattresses takes about five minutes. For the purposes of supervision and reference it is important to have a graphic representation of the whole process of disinfection. This is easily done by connecting a small steam-pipe from the stove to a pressure-gauge furnished with a metallic pencil, which is in constant contact with a card wrapped round a vertical barrel driven by a clock. The barrel is arranged to rotate completely once in twelve hours, and the diagram is divided by vertical lines, representing the time as recorded by the clock. The pressure-gauge is arranged to lift the pencil vertically to an extent corresponding with the pressure, and the diagram is ruled with horizontal lines, on which are marked the pressures and temperatures to which they correspond. The gauge is usually fitted with lock and key, and the cards,

the diagrams of which are indelible, give an accurate supervision over all disinfection which is done."

Two other high-pressure machines, which are largely used in this country, are made under Washington-Lyon's patent. The square form (Goddard and Massey) is jacketed all round the body in addition to the two doors. The jacket is usually half filled with water and is used as a boiler. The fire-grate is placed immediately under the body of the machine. The steam in the jacket is usually limited to a pressure of 20 lb., and arrangements are made to pass a current of hot air through the chamber before and after disinfection. The square shape is a constructive weakness, and the jacket forms an imperfect boiler, which cannot be properly cleaned. The oval form, generally known as Washington-Lyon's disinfector, has a separate boiler, and is made with a jacket surrounding the disinfecting chamber. It is now usually fitted with some form of patent vacuum apparatus. In the jacket, steam is maintained at a pressure of 32 lb. per square inch, but in the chamber the steam pressure is 22 lb. Under these conditions the steam in the chamber becomes superheated. By using the patent vacuum apparatus and intermitting the action of the steam good results have been obtained.

It appears to us that the machines which employ saturated steam possess many advantages over those which make use of superheated steam. The temperature in the disinfecting chamber is more uniform, and, as it corresponds to the pressure, it can be kept under complete control. Unfortunately, the employment of saturated steam under pressure necessitates a certain degree of strength in the machine which enhances the first cost. Also, the construction becomes slightly complicated, requiring intelligent supervision for the production of efficient disinfection. But, as the temperature of saturated steam corresponds to the pressure, it is possible, by using a recording-gauge, to have the whole process of disinfection under complete control. This is a matter of vital importance, and the great initial cost and expense of working appear to be justified in order to obtain such perfect results.

Where, however, the initial expense cannot be borne, recourse must be had to the low-pressure and cheaper machines, such as those of Reck and Thresh. The special features of Reck's apparatus are :—(1) the use of low-pressure steam delivered to the apparatus by an automatic regulator at a rate which cannot be exceeded ; (2) the absence of any steam jacket ; and (3) an arrangement by which a cold shower can be turned into the chamber, with the object of removing all steam from the interior in the shortest possible time after the process of disinfection is completed. The cold shower is introduced at the top of the apparatus, and falls on to a shielding arrangement, which distributes the water over a large surface and completely protects the articles from moisture.

Thresh's disinfector consists of a horizontal chamber for the infected articles, which is surrounded by a jacket containing a solution of calcium chloride of definite strength. The jacket which constitutes the boiler is heated by an ordinary furnace placed under the chamber. The steam which arises from the boiling saline fluid can be turned into the chamber or shunted into the flue at the back by means of a valve which is worked by a wheel situated on the top of the front of the machine. The steam is never allowed to accumulate at a pressure higher than that of the external atmosphere. After about thirty minutes' exposure to steam, the current is shunted into the shaft, and air is induced to enter by opening the valve of a pipe situated just below the door of the chamber. The air so entering passes through a pipe bent in a gridiron form and immersed in the boiling saline fluid, so that

the air admitted to replace the steam has nearly the same temperature as the saline fluid. To the left of the chamber and about two-thirds the way up is a small cistern, with bail-cock connected to a constant supply of water, which feeds the boiler automatically as the solution becomes concentrated. The solution of calcium chloride in water boils at 220° F., and gives off steam at about 215° F. Consequently, the steam is superheated about 3° F. The Thresh disinfector is in some ways superior to the Reck stove. In both machines steam being employed in the current condition ejects the air from the stove and from the pores of the objects to be disinfected, and so permits fairly rapid penetration. In Reck's stove, however, a temperature of 211° F. was only obtained between mattresses after thirty-five minutes' exposure, whereas in Thresh's apparatus a temperature of 212° F. was obtained in fifteen minutes. Thresh's disinfector, however, suffers from the serious disadvantage that the boiler is apt to become clogged by the saline solution, unless great care is taken to keep the solution at a constant strength. Also the jacket being used as a boiler renders cleaning a matter of considerable difficulty. In all machines which employ confined steam under a low pressure there is great difficulty in removing the air from the interstices of the objects to be disinfected. Relaxation of a low pressure does not sufficiently eject the air to secure perfect penetration. We therefore think that in low-pressure machines current steam should always be employed.

A disinfector which marks an entirely new departure in the methods of raising steam for disinfecting purposes has recently been placed on the market under the name of the "Velox." A feature of this apparatus is that the furnace consists of a series of large Bunsen burners specially designed to consume paraffin supplied under pressure. By effectually regulating the supply to the burners, it is claimed that a gallon of paraffin will get up sufficient steam and complete an operation of disinfection from beginning to end. This steam generator is known as the "flash," but as the steam so generated is apt to be superheated, it is conducted to a drum and brought into immediate contact with water. Here the superheated steam is cooled, and the water brought quickly to the boiling-point, and from this boiling water saturated steam is admitted to the chamber for disinfecting purposes. The apparatus works with either confined steam at a pressure of 15 lb., or with low-pressure current steam. Prior to the actual disinfection of articles, arrangements exist for the rapid heating of the cold walls of the chamber by passing live steam through coils of piping and sucking a current of hot air into the chamber from the casing of the steam generator, while the effectual extraction of air from the interior of the chamber and its contents is secured by an exhaust. The act of disinfection resolves itself practically into the following stages:—(1) a preliminary vacuum, subsequent to heating the chamber; (2) exposure to steam at 15 lb. pressure for fifteen minutes; (3) a second vacuum production; (4) a second exposure to steam at 15 lb. pressure for fifteen minutes; (5) emission of steam from the chamber and the conversion of the chamber into a drying-cell by passage of steam through the coiled pipes and the injection of hot air from the casing of the generator. This last act secures effectual drying of the clothes which have been treated. It is claimed for these disinfectors, whether working with confined or current steam, that the generation of steam is much more rapid than with other types of machine, and that the working expenses are trifling compared with those having coal-fed furnaces, while the attainment of disinfection is equally effectual. We have had no practical experience

with this apparatus, but from facts put before us the claims of the makers appear to be good.

In attempting to summarise the utilisation of heat as a disinfectant, it may be said that, for articles which will not be damaged thereby, boiling for five minutes will render them perfectly safe. If dry heat is used, a temperature of nearly 290° F. is required for absolute disinfection if the exposure be less than an hour. In actual practice only a temperature of 255° F. can be employed without damaging the fabrics; this temperature should be maintained from four to six hours, according to the density of the material to be disinfected. Owing to its unreliability and low penetrability, dry heat should never be used if moist heat, in the form of steam, is available. Circumstances may permit of no choice of method or apparatus, but where opportunity of selection is open, moist heat should be applied as air-free saturated steam under pressure, at 225° F., with a period of contact of not less than twenty minutes. This is not meant to imply that other forms of steam are not efficacious, for they certainly are, but it merely expresses what appears to us to be the ideal form in which moist heat should be applied for disinfecting purposes.*

CHEMICAL DISINFECTANTS.

If we limit our conception of a disinfectant to that of a substance which is capable, by its own inherent poisonous action upon a micro-organism, to destroy the life and power of development of that micro-organism, the number of practical chemical disinfectants is small. To be a satisfactory disinfectant a substance should not be too costly, it should be rapid as well as certain in its action, it should not possess chemical properties which unfit it for ordinary use, it should not produce injurious effects on the human tissues, and it should be soluble in water or capable of giving rise to soluble products in contact with the material to be disinfected. The substances which fulfil all these conditions are not numerous.

Chemical disinfectants may be solid, liquid, or gaseous; but from the nature of the case it is evident that solids must be brought into the form of a solution to enable them to penetrate throughout any substance to be disinfected. Very much the same is the case in regard to the so-called gaseous disinfectants; though generated as gases, they act best, as we shall see subsequently, only in the presence of moisture; in other words, the situation is similar to that existing in regard to dry and moist heat, and as between superheated or dry steam and saturated or moist steam. The most reliable disinfectants appear to be the following:—

Mercuric Chloride or corrosive sublimate is a well-known and highly poisonous salt. A cold saturated aqueous solution contains about 10 per cent., but two parts of boiling water dissolve one part of the sublimate. It is also readily soluble in alcohol or ether. Of a strength of 1 in 1000 in water, mercuric chloride destroys ordinary bacilli, free from spores, in from fifteen to thirty seconds. Spores require a contact with such a solution of as many minutes to ensure absolute destruction. As a disinfectant, mercuric chloride has three great disadvantages:—(1) it corrodes metals; (2) it forms with albumin an inert insoluble compound; (3) it is poisonous.

To guard against this latter fact it has been suggested to colour the

* A valuable and critical analysis of this question, by W. Defries, is to be found in *Lancet*, 1905, vol. ii. p. 984.

sublimate solution with aniline blue; thus, mercuric chloride $\frac{1}{2}$ ounce, hydrochloric acid 1 ounce, commercial aniline blue 5 grains, water 3 gallons make a solution of the required strength and of a deep blue colour. A better colour is obtained by adding 1 grain of the blue to 10 gallons; this tint is sufficiently characteristic, and does not permanently colour washing fabrics. In the absence of aniline blue any other colouring-agent may be added, such as permanganate of potash.

The relative inertness of the sublimate in the presence of albuminous materials may be prevented by acidulating the solution.

Mercuric Iodide has some advantages over corrosive sublimate as a practical disinfectant. It is insoluble in water, but soluble in an excess of potassium iodide. It has been compressed into tablets, two of which dissolved in a pint of water give a strength of 1 in 4000. "For washing floors 1 in 4000 should be employed, and for disinfecting hands and instruments a strength of 1 in 2000 is suitable." Mercuric iodide does not precipitate albumin.

Carbolic Acid (phenol), when absolutely pure, is in the form of white crystals which melt at 42°·2 C. or 108° F. The solubility of these crystals in water is about 1 in 11; a saturated solution in water will contain about 8·6 per cent. of phenol. It is more soluble in weak alkaline solutions than in water; while, when pure, it is soluble in all proportions in ether, alcohol, benzene, chloroform, and carbon disulphide.

The ordinary red or dark brown fluid sold as carbolic acid is a mixture of ortho-, meta-, and para-cresol. It is less soluble than phenol; a saturated aqueous solution will contain only about 3·5 per cent.; it is soluble in weak alkaline liquids, but is precipitated with excess of alkali. The chief impurities of commercial carbolic acid are tar oils. Their presence and approximate quantity can be estimated by shaking a measured volume of the acid with twice its volume of pure soda solution of 9 per cent. strength. The cresylic and carbolic acids are dissolved by the alkaline liquid, while the oils separate, the heavy oils sinking to the bottom, and the light oils rising to the top; their respective volumes can be then read off. These tar oils are apparently without any disinfectant properties.

Numerous "carbolic acid powders" are in the market; these are for the most part mixtures of cresylate and carbolate of lime, and have no appreciable disinfecting properties. Calvert's carbolic acid powder is a type of the best form of carbolic acid powder, as it has no lime for its basis, but is merely a mechanical mixture of the acid with the siliceous residue resulting from the manufacture of aluminium sulphate from shale. Macdougall's powder is another satisfactory preparation of this kind. It is made by adding a certain proportion of crude carbolic acid to an impure sulphite of calcium prepared from the action of sulphur dioxide on ignited limestone.

A considerable number of "carbolic acid soaps," containing more or less free carbolic acid, are also in the market. Soap alone we know to have distinct antiseptic qualities, but it is doubtful whether any of these carbolic acid soaps are of the slightest use for disinfecting purposes, or are in any way superior to ordinary soap.

Innumerable experiments have been made as to the action of phenol and its homologues as disinfectants. Their general tenor has been to show that 2 per cent. solutions of them are able to destroy the ordinary spore-free micro-organisms in from three to ten hours, but to ensure destruction of spores it is necessary to use at least 5 per cent. solutions in water and prolong the action over a day at least. Tubercle bacilli are destroyed by a 5 per cent. solution of carbolic acid in half a minute, but fresh sputum-

containing bacilli requires the addition of an equal quantity of this solution, which must be allowed to act for quite twenty-four hours in order to ensure thorough disinfection.

During recent years a number of disinfectants have come into use which are really emulsions of analogues of the higher phenols in water. These phenols are obtained by fractional distillation of the products from certain coke ovens; their precise chemical constitution is not known, but the more effective members of the group appear to have a diphenyl nucleus existing in combination with certain hydrocarbons. As met with, in the market, these preparations are milky-looking emulsions having an earthy smell coupled with a faint odour suggestive of phenol. The emulsions are made by working up thsee higher phenols with either glue and water, or resins and hydrocarbons in water, or resins, fatty acids and hydrocarbons in water. The most efficient and reliable preparations of this kind are **izal, cyllin,** and **kerol.** We have had considerable practical experience of these disinfectants and regard them as being highly efficient. They are stable and reliable, the only precaution to be observed is that, being emulsions, all dilutions should be prepared daily if possible; if not freshly made all dilutions should be well shaken before use. These remarks are applicable equally to the drums in which the crude article is sold, as there is a tendency for the constituent elements to more or less separate out after standing for any length of time. The degree of emulsification, as revealed by microscopic examination, is remarkably high. One advantage attaching to these preparations is that they are non-toxic; on the other hand, unless well diluted, they are somewhat irritant to mucous surfaces. For the destruction of ordinary spore-free micro-organisms, we have found an exposure of ten minutes in the strength of 1 per cent. to be sufficient. Anthrax spores are killed by cyllin of this strength in an hour and a half, if temperature be maintained at 135° F. Their inhibitory or antiseptic value is equally defined, as neither spores, micrococci or non-sporing bacilli can germinate in medicated media if the amount of these disinfectants added is 0·1 per cent.

Lysol is a solution of cresol in soap; it mixes well with water, and as a 2 per cent. solution destroys ordinary bacteria in an hour. It is an excellent deodorant and of low toxicity.

Liq. Cresyli Saponatus is a similar elegant preparation of the cresols. It is an effective re-agent, but having, roughly, only one-third the disinfectant value of the higher phenol emulsions.

Lysoform is an emulsion of formaldehyde in fatty acids combined with an alkali. It contains 4 per cent. of formaldehyde and is equivalent to 10 per cent. of commercial formalin.

Permanganate of Potassium is a popular disinfectant, but, effective as it undoubtedly is as a germicidal agent when allowed to act against ordinary bacteria in the absence of organic or other oxidisable matter, it must be borne in mind that, in the presence of organic material its disinfectant value is very much reduced. On these grounds we are disposed to think that it may be overrated as a practical chemical disinfectant.

Formalin is another chemical disinfectant in very general use. It is practically a 40 per cent. solution of formaldehyde. For routine use in the disinfection of ordinary articles or materials needing disinfection, we are disposed to give it no high place owing to the fact that, when it comes in contact with albuminous material, it tends to form a hard protective layer on the surface which effectually reduces its penetrative power, with the result that micro-organisms in the depth of the mass escape destruction.

As will be explained subsequently, the value of this preparation is greater in the vaporised state than in that of a simple solution.

An important consideration in regard to all these re-agents in this series is their *working strength*. If, for example, we know that any given disinfectant will kill ordinary bacteria at a strength of 2 per cent., it is absolutely useless to add a little of a 2 per cent. solution if no regard be paid to the need of securing the presence of the re-agent to the extent of 2 per cent. of the whole weight or volume. This essential condition in practical disinfection is constantly overlooked, and more particularly where attempts are made to disinfect or destroy micro-organisms in excreta. In all cases the intimate mixture of the fæcal mass with the disinfectant must be secured, and in no way can this be better done than by deliberate stirring up of the whole by means of a stout stick or wooden spoon. It may be assumed that the volume of an average stool, as passed from a patient, is not less than 8 fluid ounces or 230 c.c., and to this must be added a proportionate volume of the stock solution or emulsion of whatever re-agent is being used, and the whole mixed intimately. The working strengths of such stock solutions must be based on results obtained in previous laboratory experiments. Say we elect to use cyllin or some similar preparation which kills ordinary bacterial forms in a strength of ½ per cent.; therefore, to expect to disinfect effectually a fæcal or other mass with a stock solution of 1 in 100, we must add a volume equal to that of the stool, and intimately mix, the final dilution will then be 1 in 200. From experimental data furnished by Fowler,* we suggest that the stock solutions or emulsions of certain common disinfectants may be placed at the following strengths :—mercuric chloride 1 in 50, the same in the presence of an acid 1 in 180, phenol 1 in 20, izal 1 in 50, cyllin 1 in 100, kerol 1 in 100, liq. cresyli sap. 1 in 30, lysol 1 in 25, lysoform 1 in 1½, permanganate of potassium 1 in 80, formalin 1 in 14. The practical conclusion to be drawn from this statement is that we are in the habit of using, for routine disinfection, an acid solution of mercuric chloride which is nearly five times too weak for the rapid disinfection of excreta. In other words, the official stock solution in general use is a dilution of 1 in 960, while, if we want rapid and effective action on fæcal material it should be at no greater dilution than 1 in 180. This would be represented by 1 gramme of the bichloride, 2 c.c. of strong hydrochloric acid, made up to 180 c.c. with water. This, added to an equal mass volume of excreta, would mean an actual working dilution of 1 in 360.

Chlorine holds the first place among the gaseous disinfectants in common use. It may be prepared for disinfection work by heating together a mixture of common salt, manganese dioxide, and sulphuric acid, or simply by the action of hydrochloric acid on manganese dioxide. Both these processes are somewhat inconvenient, and it is more easily evolved from chloride of lime ($CaCl_2,Ca(ClO)_2$) or bleaching-powder by the addition of an acid; thus $CaCl_2,Ca(ClO)_2+2H_2SO_4=2CaSO_4+2HCl+2HClO$; then $2HCl+2HClO=2Cl_2+2H_2O$. Theoretically, bleaching-powder contains 56 per cent. of chlorine, but it is doubtful whether the whole of this gas is obtained on decomposition. Practically, one pound of the powder, on being treated with sufficient acid to decompose it completely, will evolve about 2·8 cubic inches of chlorine gas. In ordinary air, 5·4 parts of chlorine per 100 cubic feet of air appear to be necessary to kill all micro-organisms. If the air be moistened, which may be done by wetting the walls, floors, &c., and by diffusing steam, 0·3 per cent. by volume in each 1000 cubic feet of air

* Fowler: "The Working Efficiency of some Disinfectants," *Journ Roy. Army Med. Corps*, vol. vi. p. 6.

is sufficient, disinfection being complete in from five to eight hours. This quantity of the gas can be generated, practically, by decomposing 1½ lb. of chloride of lime with 6 ounces of strong sulphuric acid for each 1000 cubic feet of space to be disinfected. Or, as an alternative, for the same cubic space the following should be used :—Common salt, 8 oz. ; manganese dioxide, 2 oz. ; sulphuric acid, 2 oz. ; water, 2 oz. ; the water and acid to be mixed together, and then poured over the other ingredients in a delf basin, which should be placed in a pipkin of hot sand. Or, four parts by weight of strong hydrochloric acid may be poured on one part of powdered manganese dioxide. Chlorine decomposes hydrogen and ammonium sulphides at once, and more certainly than any other gas. It doubtless destroys organic matter in the air, as it bleaches organic pigments, and destroys odours, either by abstracting hydrogen, or by indirect oxidation. Its action, however, depends greatly upon the humidity, disinfection by chlorine in dry air being very uncertain. It is an extremely irritant, poisonous gas, and being very heavy tends to fall, necessitating the generating vessel to be placed in an elevated situation, in order to secure anything like equal diffusion. Carpets, curtains, &c., should be removed and disinfected by moist heat, as chlorine fails to destroy organisms in them, and they themselves would be injured by its action.

Chlorine fumigation, carried out under the best conditions, may fail, and often does fail, to disinfect spore-holding material covered over or lurking in chinks or cracks. Delépine and Ransome's observations, upon the practical disinfection of tuberculous rooms by chlorine, show clearly that, as often perfunctorily carried out, attempts at disinfection by chlorine gas are fallacious. These observers recommend that, in place of evolving the crude gas from inconvenient apparatus, the chlorine in the nascent state may be generated in the places required by thoroughly washing all parts of a room with a 1 in 100 solution of bleaching-powder. After the application of the solution, chlorine continues to be evolved so long as all the chlorinated lime has not been decomposed, and that without anything further being required to be done.* If needed, it is easy to increase its activity by adding an acid to the solution, or by saturation of the air of the rooms with acid fumes, and by raising the temperature. For safety, this washing with choride of lime water must be repeated three or four times in succession. The room may be closed afterwards, a small petroleum stove being first placed in the middle of the chamber, precautions being taken to prevent any chance of fire. Over this stove a large tin basin full of acidified water or chlorinated lime solution should be placed.

Disinfection by chlorine in this way should be complete in less than three hours. Bleaching-powder itself does not spoil things as much as one would expect, and can be used as indicated in rooms from which all draperies and carpets have been removed without any fear of damage, provided the walls and ceilings are not decorated with valuable paintings or papers. The quantity of powder required for a room measuring 10 feet in all directions would not be more than 8 ounces, and the quantity of water 3 pints for one washing.

Sulphurous Acid or sulphur dioxide has been for many years the most common and favourite disinfecting agent, owing to its cheapness and the ease with which it can be generated. This gas is formed whenever sulphur is burned in air or oxygen. It is usually generated by burning roll sulphur ; the room is sealed up as hermetically as possible, the sulphur

* Delépine and Ransome : "Report on the Disinfection of Tubercle-infected Houses," *Brit. Med. Journal*, 1893, vol. ii. p. 990 ; also *idem*, 1895, vol. i. p. 349.

lighted in some suitable receptacle, and allowed to burn as long as it will. A still more convenient method is to take an ordinary benzoline lamp, fill it with carbon bisulphide, and light; as the carbon bisulphide is consumed, the sulphur is evolved as sulphur dioxide. The generation of sulphur dioxide by these means is now largely superseded by the employment of sulphurous acid liquefied under pressure, which is supplied by the manufacturers in cylinders available for convenient use. When sulphur is burned in a perfectly closed space, its consumption is limited by the quantity of air in that space; theoretically, a cubic foot of air will burn up 634 grains of sulphur, but it will not do this unless freely supplied with air. One pound of sulphur, when completely burnt, gives off 11·2 cubic feet of sulphur dioxide, which for 1000 cubic feet of space gives 1·12 per cent. With the addition of alcohol under careful experimental conditions, 40 per cent. of the possible total quantity of sulphur in a closed space can be burnt, but in ordinary rooms not much more than 20 per cent. is usually consumed. To attain the maximum consumption, the sulphur must be broken up into pieces not larger than a hazel-nut, and divided about a room, never putting more than 1 lb. in any one vessel.

The bactericidal or disinfectant value of sulphurous acid has been extensively investigated by Cash * and others. On the whole, their results have been unsatisfactory, though, on the other hand, Dubief and Bruhl found it to be an effectual germicide, especially when the air is moist. It has been proved over and over again that the best results with this agent can only be obtained under very strict experimental conditions, such as are quite unattainable in ordinary circumstances. The best results are obtained by well moistening the sulphur with methylated spirit, when, under the most favourable conditions, the air of the room thus disinfected may contain 10 per cent. of sulphur dioxide. Koch's experiments show that even when present to this extent, and the air saturated with moisture, micro-organisms grow vigorously after twenty-four hours' exposure. To obtain this percentage of sulphurous acid gas in the air, even under favourable circumstances, it would require at least 10 lb. of sulphur to be burnt for each 1000 cubic feet of air space; as, however, it is impossible to burn up all the sulphur, even this quantity would not yield the amount of SO_2 theoretically required. As the disinfection of any given place is usually a complex operation, involving afterwards mechanical processes of scrubbing and cleansing, it is possible that a less quantity may suffice, but in any case this should not be placed at a lower limit than 3 lb. of sulphur for each 1000 cubic feet of space. Too great reliance, however, must not be placed upon disinfection by means of sulphurous acid; at best it is an uncertain agent, and distinctly inferior to either chlorine or formaldehyde. The slightest covering will protect micro-organisms from its action.

If precautions are taken to reduce leakage to a minimum, by careful pasting over and closing of holes, cracks and crevices, disinfection of surfaces by means of fumigation with either of the above-mentioned gases may be able to destroy most, if not all, of the freely exposed and less resistant micro-organisms; more than this cannot be expected.

Formaldehyde.—The value of formaldehyde as a gaseous disinfectant has been established by the work of many observers. The gas may be generated in various ways. The first experiments aimed at its generation by the evaporation of ordinary formalin in an open dish. By this method, so much paraform or inert solid formaldehyde is produced that no reliable

* Cash: "Report on the Action of Disinfectants," Supp. to 16th Ann. Rep. Med. Off. Loc. Gov. Board, 1886–7.

quantity of the active gas can be obtained. Following this, special lamps were devised for generating the gas from methyl alcohol. The best of these was the Formogène Richard. This lamp is composed of a reservoir for the methyl alcohol; from the bottom of the reservoir the methyl alcohol is led to the burner by a U-shaped tube. The burner resembles in construction an Argand burner, and is so arranged that it can be covered with a cup or brass bell, the upper part of which is formed by a wire case containing platinised asbestos. So long as air is allowed to reach the wick from below, the spirit continues to burn with a flame even after the bell has been placed over it; but by closing the lower part of the tube the flame is extinguished. If the flame is put out after the platinised asbestos has been heated sufficiently, the alcoholic vapours will continue to rise, and, on coming in contact with the hot, finely divided platinum, will become oxidised so as to form formic aldehyde and water. Air is supplied to all the parts of the wire case containing the platinised asbestos. A lamp holding three litres of methyl alcohol and supplied with three burners generates formic aldehyde gas in sufficient quantity to disinfect a room of 2500 cubic feet. Very good results with this lamp were obtained by Delépine, Kanthack, and others. In some observations made by ourselves we found that a litre of wood-spirit was required for every 1000 cubic feet; but, as wood-spirit of the proper quality and strength costs about 10*s.* per gallon, the expense of the process militates against its universal adoption.

A second method of generating formaldehyde is to convert solid paraformaldehyde into gas by heating it in the presence of water vapour. This is known as Schering's method, and in Germany the "Aesculap" lamp is employed for this method of disinfection. Tablets of paraformaldehyde, each of which weighs one gramme, are placed in the upper portion of the lamp, and are then converted into gas by the heat and moisture derived from the combustion of methylated spirit. In England "Alformant" lamps have been devised for Schering's method, but they give too small a quantity of water for the best results.

Flügge states that 250 tablets should be vaporised in the Aesculap in order to disinfect a room having a capacity of 100 cubic metres, or, say, 3500 cubic feet.* We have had considerable experience with the "Alformant" lamps, and find that to ensure disinfection of walls and other exposed surfaces in carefully closed rooms at least thirty tablets of paraform must be volatilised for each 1000 cubic feet of space; moreover, no single lamp is capable of diffusing the generated formaldehyde over a greater cubical space than 4000 feet, and that, when attempts are made to disinfect large rooms with these lamps, one lamp must be apportioned to each 350 square feet of floor area, vapourising from it not less than 120 tablets. Even then discrepancies are liable to occur in regard to the efficiency of the operation, the disturbing factors being humidity and temperature, more particularly the former; the nearer the hygrometric state of the air approaches saturation and the warmer it is, the better will be the results. The room should be left closed for at least six hours after completion of volatilisation.

Trillat, one of the first workers with formaldehyde vapour, volatilised formalin mixed with calcium chloride under a pressure of three atmospheres from an autoclave. This method has not found much favour, owing to the expense involved in working with an autoclave. Since then, three other special generators have been well spoken of; these are Lingner's lamp, the Trenner-Lee apparatus, and the "Torrent" vaporiser.

* Flügge: "Room Disinfection by Formaldehyde," *Zeitschift f. Hygiene*, vol. xxix 1898.

In Lingner's lamp the formalin, which is contained in the central receiver, is projected from four nozzles as a fine spray, under the pressure of the steam developed in the ring boiler, and in streams so forcible that three pints of formalin and two pints of water are vaporised and distributed through a cubic space of 3500 feet in half an hour. If the room or space operated on be kept closed for six hours on completion of the vaporisation, the sterilisation of all exposed surfaces is usually complete. In our hands, this lamp has been found handy, reliable, and safe. Polymerisation is prevented by the manner in which the combined formaldehyde and steam are projected together into the air. The lamp can be used from the outside of a room by adjusting through a keyhole a flexible metal tube with mouthpiece, which is provided. Our best results have been obtained when the lamp has been worked within the room itself.

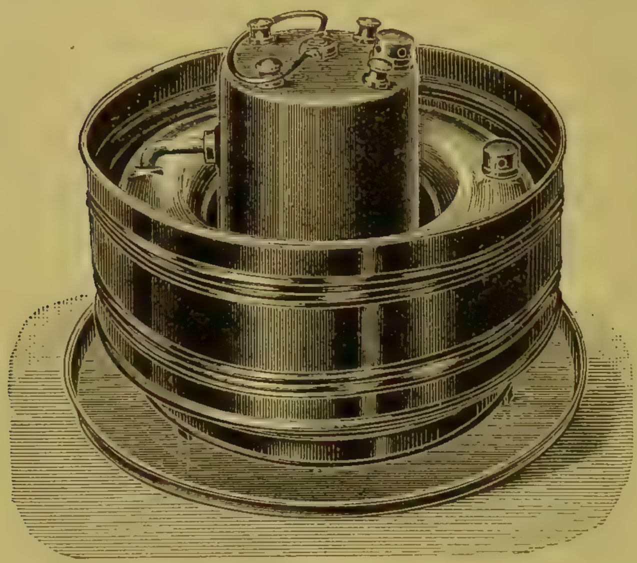


FIG. 157.—THE LINGNER FORMALDEHYDE GENERATOR.

The Trenner-Lee apparatus (Fig. 158) works from either outside or inside the room to be disinfected, without pressure and automatically. It consists of a heavy copper retort from which a known quantity of formalin can be rapidly and conveniently vaporised. The emerging vapour is practically superheated by the escaping products of combustion from the spirit-lamp beneath. No attention is required after filling the apparatus and lighting the lamp, which, containing a definite amount of spirit, is allowed to burn itself out. The main essential for success with this retort is the vaporisation of a sufficient volume of formaldehyde solution. From our experience, this may be put at not less than 10 fluid ounces or 285 cubic centimetres of formalin, with 3 c.c. of glycerin for each thousand cubic feet of space. One of these vaporisers is sufficient for 5000 cubic feet; in all cases the room should be kept closed for at least six hours after completion of the operation.

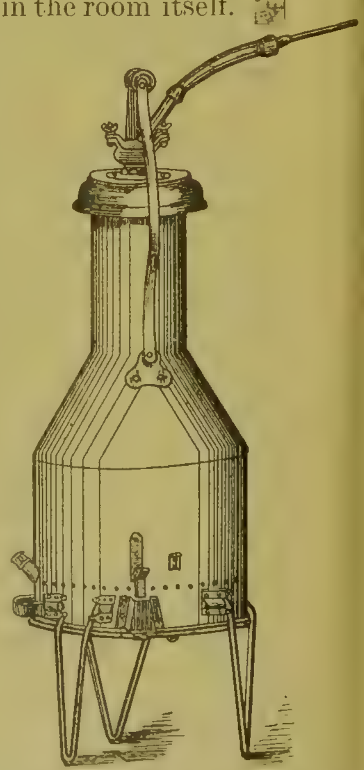


FIG. 158.—TRENNER-LEE FORMALDEHYDE GENERATOR.

The "Torrent" vaporiser is very similar in principle to the Trenner-Lee, and gives good results. It consists of a vessel or boiler which contains the formalin to be gasified. It is closed by a cover which carries two distributing tubes fitted with nozzles. The vessel rests in a mantle below which is the source of heat in the form of a spirit-lamp. The consumption of formalin with this apparatus works out very much the same as for the Trenner-Lee, or half a pint for each 1000 cubic feet. On completion of the vaporisation, the room should be left closed for at least six hours.

In all three of these apparatus, the solution of formaldehyde to be volatilised has been given as formalin. It is true this is the most convenient to be used; but should this not be available, then the paraform tablets as used in the "Alformant" lamp may be employed; if crushed they dissolve in the hot water, forming a nearly pure solution of formaldehyde (15 per cent.), which is gasified in a similar manner as ordinary formalin. Our own observations indicate that when solidified formaldehyde is used in this way to make a solution from which the gas can be vaporised in an active state, one hundred tablets must be dissolved or placed in a litre of water for each 1000 cubic feet of space to be treated; this will give results comparable with those obtained by the vaporisation of ordinary formalin. For lesser or larger cubical areas the number of tablets taken and the volume of water in which they are to be dissolved must be calculated in the same proportion, on a basis of ten tablets in 100 cubic centimetres of boiling water, for each 100 feet of cubic space. For purposes of fumigation, formaldehyde has advantages over sulphurous acid and chlorine in its lower density, which gives it a greater diffusibility and some power of penetration, and in its more rapid action. It acts best when the air is moist, the optimum humidity being 75 per cent., and when the air has a temperature of 70° F. At air temperatures below 62° F., polymerisation of formaldehyde gas begins, and becomes more marked as the temperature decreases, which is evidenced by the persistent hazy condition of the air of the room. Formaldehyde is harmless to most colours and to most surfaces except iron. The vapour is irritating but readily cleansed away by ventilation.

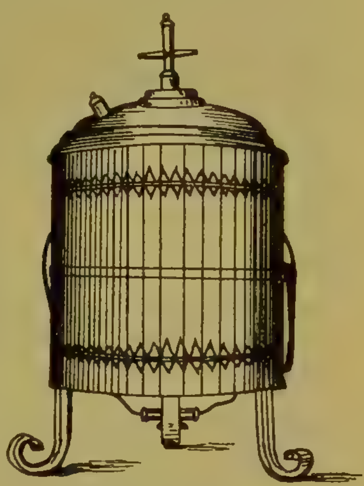


Fig. 159.—The "Torrent" Formaldehyde Generator.

Apart from the use of lamps and special generators, the practical employment of formaldehyde as a disinfecting agent is secured by its direct application to infected surfaces by means of sprayers. In theory, this is a very excellent method, but in actual practice it is far from satisfactory. Unless the spraying is done thoroughly it is useless, and in most cases close personal supervision of the workers is needed to secure this. To carefully spray a large wall surface is a slow and laborious operation, and when the re-agent employed is endowed with such irritant properties as formaldehyde possesses there is much temptation to the operator to shirk the duty. Too often the whole act of spraying is done perfunctorily and without any attention to such details as, how much surface is there to be sprayed over, and how much, or of what strength, solution must be applied? Our own observations, using an Equifex spray with formaldehyde, indicate that 8 fluid ounces of formalin in 1 gallon of water are only just sufficient to effectively cover 600 square feet of surface; if this volume of disinfectant be reduced, or the area of its application be increased, effective disinfection of the surface cannot be relied on. The value of spraying such a re-agent as formaldehyde depends partly on the immediate effect of its direct application to, or contact with, an infected surface, and partly on the secondary volatilisation of the gas which accompanies the gradual drying of the damped surface. The possibility of preventing polymerisation during this latter stage will depend on how far the temperature of the air space can be maintained above 62° F. The main value of the spray method appears to be that formaldehyde continues to be supplied to the air of the room for a

long time, whereas, in other methods, the percentage of the gas begins to diminish by leakage from the moment the generation is finished.

A modification of the practice of spraying formaldehyde solution (formalin) direct on to wall surfaces is to spray the re-agent on to one or two sheets hung up in the room in a slanting position at an angle of about 45°. It is better to render them damp to the touch before hanging up, as the formalin is absorbed more quickly by the fibres. We have tried this method and found it effective, while Ravenel and Gilliland * speak most enthusiastically of it. A clear pint of formalin should be used for each 2000 cubic feet of space.

Under circumstances in which neither a special vaporiser nor a spray is available, the following process, suggested by Evans and Russell, † will be found most efficient. The method consists in pouring formalin quickly upon fine crystals of potassium permanganate, contained in a suitable metallic vessel; a vigorous action takes place in a few seconds, accompanied by a strong ebullition of the liquid and sufficient heat to produce a large quantity of steam. The reaction is over in a few minutes, and with a proper proportion of substances the residue in the vessel is almost dry. The heat produced by the action of the permanganate on a portion of the formaldehyde is sufficient to evaporate nearly all the remainder. Analyses of the gas evolved by this reaction show it to consist of formaldehyde, water vapour, carbon dioxide, and traces of formic acid. In the generator are left a lower oxide of manganese, a little formaldehyde, carbon dioxide, potassium hydroxide, and some potassium formate. The precise nature of the decomposition is apparently according to the following reaction: $4KMnO_4+3HCOH+H_2O=4MnO(OH)_2+2K_2CO_3+CO_2$. From this equation it would seem that one-fifth of the formaldehyde is destroyed. The proportion of the two substances which gives the best results and the driest residue is two parts of formalin to one part of the permanganate. We have submitted this method to a large number of experimental observations and found it to be effective, simple, rapid, and, by virtue of the inexpensive apparatus required, preferable to the older and more cumbersome methods. For a space of 2000 cubic feet, 285 grammes or 10 ounces of the permanganate and 570 cubic centimetres or 1 pint of formalin are needed, the re-agents being mixed or added the one to the other in an ordinary galvanised iron pail. The permanganate must be put in first and the formalin poured on to the crystals; a brisker decomposition of the formalin results if the crystals of the permanganate be finely crushed, but this is not essential, as the ordinary permanganate crystals are sufficient. After placing the two re-agents in the pail or other metal vessel, some seconds elapse before evolution of formaldehyde begins, and there is ample time for the operator to withdraw from the room, which should be left closed up for quite six hours.

In cases where formalin is not available, as in camps and other places where liquid re-agents are not readily transportable, a working solution of formaldehyde can be made from the ordinary tablets of solid paraform. These need to be crushed up to a powder and then placed in hot water; the liquid is then brought rapidly to the boil. This is now a hot solution of formaldehyde and should then be poured on to so much permanganate in a suitable vessel as already explained. From our own experiments, we find that practically one hundred tablets, if crushed and then dissolved in a pint

* Ravenel and Gilliland: *University of Pennsylvania Medical Bulletin*, vol. xvi. p. 77.

† Evans and Russell: "Formaldehyde Disinfection," 13th Annual Report, 1904, State Board of Health of Maine, U.S.A.

of boiling water, make a solution of formaldehyde equivalent to 300 c.c., or say half a pint of ordinary formalin. If this boiling solution be poured upon 10 ounces of permanganate crystals, sufficient formaldehyde vapour in an active form is liberated to secure the same disinfecting results as would be obtained by pouring half a pint of commercial formalin on to 5 ounces of permanganate. For a space of 2000 cubic feet, or say from 180 to 200 square feet of floor area, the solution of two hundred tablets, after crushing, should be made in from 1½ to 2 pints of boiling water, and this solution poured on from 15 to 20 ounces of permanganate. In all cases the amount of permanganate needed is exactly half the weight of the liquid added, that is, 600 c.c. of formalin need 300 grammes of permanganate, and two hundred tablets dissolved in 30 ounces of water require 15 ounces of the crystals.

For the rapid disinfection of a limited amount of clothing, we have found the following procedure as efficient as it is simple and easy to carry out. Obtain a well-made box or trunk whose lid fits closely. Make a rough estimate of its cubical capacity. Place the articles to be treated inside, taking care not to pack them or press them down, but to lie simply as they fall or are dropped in. At one end of the box, or in any convenient part, place the metal container in which the necessary decomposition of the formaldehyde solution is to be secured. Into this container put the permanganate crystals and then add the formaldehyde solution. The box may now be closed and rendered as air-tight as possible, and left for from three to four hours. For a box containing 5 cubic feet, the use of 2 ounces of formalin with 1 ounce of permanganate is sufficient, or if the tablets are employed, then twenty of them dissolved in 8 ounces of boiling water; this is then to be poured on to 4 ounces of the permanganate.

In spite of the extensive use of formaldehyde for disinfection purposes, it is doubtful whether many operators have any idea of how much of the gas they are employing, how it acts, or how much of it is available in the air of the rooms into which they generate it. The difficulties in the way of making accurate estimation of formaldehyde in air account possibly for much of this apparent empiricism. Von Brunn,* who made three determinations of the amount of formaldehyde in the air of a charged room, recovered only 17 per cent. of the total weight of formaldehyde introduced into the room, and concludes that the greatest portion of the liberated gas is condensed at once on the surface of the walls and on the objects in the room. If so, the idea that in disinfection the formaldehyde acts as a gas is incorrect. He goes on to say that "the more experiments have been made with formaldehyde, the more has it been observed that its maximum germicidal effect can only be attained in the presence of an abundance of water vapour. Therefore, it appears that, by vaporising formaldehyde, we only accomplish a uniform distribution of the disinfectant in space, but that the real efficacy lies not in the formaldehyde gas, but in the solution which condenses everywhere on surfaces." Jorgensen † found that paper, cloth, &c., condense formaldehyde from moist air laden with it, and that a room with wooden walls, having been charged and then ventilated for several days until the odour had vanished, and closed again for more than a month, had developed such a smell of formaldehyde when opened that it was unendurable. He concludes that the total surface of walls in rooms

* Von Brunn: "Formaldehyddesinfektion durch Verdampfung." *Zeitsch. f. Hyg. u. Infektionskht.*, 1899, Bd. 30, p. 201.

† Jorgensen: "Untersuchungen u. Formaldehyddesinfektion." *Zeitsch. f. Hyg. u. Infektionskht.*, 1903, Bd. 45, p. 237.

is important, and that proportionately more formaldehyde should be introduced when there is a large wall surface to compensate for the greater condensation, and thus leave the same amount of gas in the air as would be present in a smaller room with less condensation. We confess to much sympathy with this view, and think that hitherto too much stress has been laid on mere cubical capacity of rooms, and that sufficient allowance has not been made for the extent of superficies on which the gas has to act.

Approaching the subject from another point of view, some interesting facts as to formaldehyde disinfection are given by Base.* Working in a specially constructed chamber lined with zinc and presenting little material on which formaldehyde gas could condense or by which it could be absorbed, he found that, on days with a moderate breeze and using various means of generating the formaldehyde, the air of the room contained at the end of an hour about 30 per cent. of the total weight of formaldehyde introduced. Unless unrecorded sources of leakage existed in Von Brunn's experiments, the difference between the amounts of formaldehyde recovered from the air by him and by Base appear to be only explicable by the assumption that Von Brunn's experiments were made in an ordinary room with objects in it and walls of absorbing materials. Taking into consideration the conditions under which an ordinary act of fumigation with formaldehyde is carried out, it may be assumed that, at the end of an hour, some 20 per cent. of the total formaldehyde generated is present in the air of the chamber into which it is generated. With both the Trenner-Lee retort and the permanganate-formalin method, Base found that, at the end of twenty minutes or so, the air of the room contained 0·05 gramme of absolute formaldehyde per cubic foot. Similar amounts have been found when using other forms of generator. The following conclusions as to the practical requirements for an effective formaldehyde disinfection are given by Werner †:—(1) In all cases, an average of 5 grammes of absolute formaldehyde per cubic metre or 14·16 grammes per 100 cubic feet should be used with seven hours' action. (2) In exceptional cases, where loss of formaldehyde cannot be avoided, or where numerous objects, or a good deal of matter of an organic nature which cannot be conveniently removed, are present in the room, the quantity of formaldehyde should be doubled. (3) In all cases where the room temperature is below 50° F. it should be raised; from 68° to 77° F., is an efficient temperature. (4) The strength of the formaldehyde solution should be known.

In addition to the foregoing, numerous other chemical re-agents have from time to time been suggested as disinfectants. Of these, **iodine** is not well adapted for use as a fumigating agent, chiefly on account of the density of its vapour, which is 8·5 times heavier than air, rendering its equal diffusion very difficult. **Iodine tri-chloride** possesses marked disinfectant properties in solution of 1 per cent., but its chief value lies in its antiseptic powers, 1 in 3000 preventing the growth of a variety of pathogenic organisms; there is one exception, however, that of the enteric fever bacillus, which resists even a solution of 1 in 500. **Bromine** has been employed as a gaseous disinfectant, but with indifferent success. **Lime** has a powerful germicidal effect, which has been shown to be due to its alkalinity; a 0·1 per cent. solution of quicklime sterilises excreta after five hours' exposure. Of the many other substances commonly regarded

* Base: "Formaldehyde Disinfection," Bull. 27, U.S. Public Health and Marine Hospital Service, 1906; also see *Journal of the American Chemical Society*, 1906, vol. xxviii. p. 964.

† Werner: "Zur Kritik der Formaldehyddesinfektion." *Archiv. f. Hygiene*, 1904, Bd. 50, s. 305.

as disinfectants, we may mention the **sulphates of copper, iron,** and **zinc,** also **chloride of zinc** and the **hypochlorites.** All these need to be of 5 per cent. strength, and even then either take several days to kill anthrax spores, or fail to do so. Of the many other chemical and patented substances that have been brought forward at various times as disinfectants, none have been proved to be efficacious in the exhaustive way that mercuric chloride, carbolic acid, izal, cyllin, and kerol have been tested. The greater number are really only antiseptics or deodorants, of considerable value as such, but not to be considered as true disinfectants.

Disinfection of Clothing and Bedding.—All articles of little value should be burnt. The application of heat in some way is the most sure and at the same time usually the most practicable method of disinfection. For bulky articles, such as bedding, blankets, and clothing generally, moist heat or saturated steam will be found the most efficacious. In the case of bedding, the hair or feathers in mattresses or pillows may be taken out and loosened before exposing them to disinfection by heat. Where moist heat cannot be applied or obtained, exposure to dry air at or above 250° F. for about four hours should be secured ; but in no case should efforts at disinfection by means of dry heat be substituted for moist heat when the latter procedure is available.

In circumstances where no means exist for disinfecting bulky articles of clothing and bedding by these methods, they should, if possible, be destroyed by burning; failing that, they should be allowed to soak for some hours in some disinfecting liquid, such as one of the following :—Acidified mercuric chloride 1 in 960, carbolic acid 1 in 40, izal 1 in 100, cyllin 1 in 150, kerol 1 in 150, permanganate of potassium 1 in 80, or lysol 1 in 20. After soaking in any one of these solutions, the clothing should be boiled and washed thoroughly with soap and water.

Disinfection of Excreta and Discharges.—The urine and bowel discharges so frequent in enteric fever, cholera, dysentery, and diarrhœa should be received into a vessel containing either carbolic acid solution (1 in 20), or acidified mercuric chloride solution (1 in 180), or izal (1 in 50), or cyllin or kerol (1 in 100), with a further application of an equal quantity of the disinfectant directly afterwards. The whole should be well mixed, left for half an hour for the disinfectant to act, and then either burnt, buried, or discharged down the closet; if the latter is used, it should be well flushed afterwards with water.

The Newcastle Steriliser, patented by Goddard and Massey for the treatment of enteric stools, is used in several towns. The fæces are collected in a pan standing in a small off-shoot from the ward. Steam is then turned into the bottom of the liquid until a temperature of 250° F. is reached. The fæces, thus effectively sterilised, are passed into a cooling tank, and when cooled to 100° F. are allowed to flow away to the sewers. In cholera and yellow fever, the vomited matters should be treated in the same way as the stools.

The same care needs to be observed in the treatment of all other discharges from the sick. Thus, all discharges from the mouth, throat, nose, and lungs in diphtheria, whooping-cough, scarlet fever, small-pox, measles, and phthisis should be wiped away with pieces of rag in place of handkerchiefs ; these rags should be burnt after use. Failing this, they should be treated in a similar manner as an infectious stool. In diphtheria and scarlet fever direct application of some disinfectant is advisable. In scarlet fever and small-pox, when the infective matter exists in the skin particles so freely given off, care should be taken to render these particles innocuous. This

can, to a large extent, be accomplished by washing the skin with warm water and soap, and then smearing the body surface night and morning with a medicated oleaginous preparation made by mixing three drachms of eucalyptus oil in 8 fluid ounces of olive or almond oil. In the same diseases much good results from syringing or swabbing out the mouth and nose with a warm solution of cyllin or kerol (1 in 400), or izal (1 in 200), and then burning the swab after use.

Deodorisation of Excretal Discharges.—Apart from their disinfection, it is often convenient and necessary to deodorise excretal discharges. For this purpose, few means are better than well-powdered dry *earth*, especially humus, marly, and clayey soils. *Charcoal* may be used for the same purpose, but it soon loses its power. *Quicklime* and *chloride of lime* are also valuable, the latter, in particular, being most powerful as a deodorant and also as a steriliser. Quicklime, 5 parts, and carbolic acid, 1 part, make a good deodorising mixture.

The preparations in the form of special powders are various, the best perhaps being the different *carbolic acid powders* already alluded to; to these may be added such preparations as *ferralum* and *cupralum*. The latter consists of sulphates of copper and aluminum with potassium dichromate and terebene. It is a fairly powerful deodorant, counteracting ammonia and hydrogen sulphide, and at least masking fæcal odour as much as carbolic acid.

The substance advertised as *Sanitas* is a hydrocarbon derived from turpentine acted upon by steam. It has the advantage of being easily miscible with water, but it is not very powerful either as a deodorant or antiseptic.

Chlor-alum is a weak solution of chloride of aluminum; it is not a very powerful deodoriser, and must be used in large quantity, but its cheapness and lack of poisonous properties are recommendations, and when in sufficient amount it is effectual. It is efficacious against ammonia, but not against hydrogen sulphide; it acts moderately against fæcal odour. *Burnett's fluid*, which contains 25 grains of zinc chloride to every fluid drachm, if used in strength of 1 pint to a gallon of water (1 to 8), will deodorise excreta. *Potassium permanganate*, in the form of Condy's fluid, prevents putrefaction for a short time, and removes the fæcal odour, but it requires to be used in large quantity. *Sodium manganate* has similar powers, but needs to be used freely.

These substances are all good deodorants and arresters of putrefaction, but must not be regarded as disinfectants. Practically, their use is very limited, and should not be encouraged, as they clog pipes and drains and give rise to false ideas of security.

Disinfection of Rooms and Furniture.—An agent of the first importance for the disinfection of rooms is undoubtedly the free perflation of fresh air, while all woodwork should be well scrubbed with soft soap and hot water, or washed with a corrosive sublimate solution (1 in 5000) or chloride of lime (1 in 100). The walls also should be well washed with the same solutions. The experiments of Chamberland in France, and Delépine in this country, leave little doubt that washing with chloride of lime gives the most satisfactory disinfection of all surfaces to which it can be applied. The difficulty of ordinary room disinfection is that the surfaces and objects to be treated are unduly injured, not merely by this corrosive chemical, but by the process of washing with any liquid. An attempt to overcome this objection has been made by means of spraying. The chief disadvantage of the spray method is the discomfort experienced by the

operator if the process is efficiently carried out. When formaldehyde is employed some protection for the eyes is necessary. Corrosive sublimate (1 in 1000) is used in Paris for the sprayers, and though no cases of mercurial poisoning have occurred, still the operators appear at times to suffer from troublesome cough and vomiting. Carbolic acid, lysol, and solutions of the hypochlorites have also been employed for the spray method, but are not so useful as formaldehyde solution. For the disinfection of ships, the spray method is strongly to be recommended.

In whitewashed rooms the walls can be readily scraped, and then well washed with a solution of chloride of lime. In the case of papered walls all the layers, if there be more than one, should be stripped off and the walls washed with the lime before being re-papered. Ceilings need to be scraped and washed with lime in the same way. All fabrics must be removed from infected rooms, and subjected to disinfection by moist heat. All articles of furniture, of wood or metal, must be washed with soft soap and hot water.

As an additional precaution, rooms may be fumigated for three or more hours with formaldehyde vapour, the doors and windows being subsequently opened, and kept open for twenty-four or thirty-six hours. Fumigation of rooms, unless supplemented by careful washing and scrubbing, is practically valueless. In fact, we may say that, in our opinion the routine fumigation and so-called disinfection of rooms is largely a farce and a waste of time and money. In the majority of cases, where carried out it is unnecessary, as the infection pertains to the occupants of the room, to their persons and clothing, rather than to the walls, floors, or ceilings. This is especially the case in such affections as measles, scarlet fever, diphtheria, and whooping-cough ; it seems desirable that the charlatanry which still appears to exist in this question of disinfection should be abandoned. If fumigation is performed, it must be clearly understood that it is quite a subsidiary proceeding, and that it can only be done effectually when the room is unoccupied, as the air must be rendered quite unfit for respiration. For the purification or deodorisation of mortuaries and dead-houses, fumigation with formaldehyde or chlorine is both useful and practicable, but their actual disinfection will be best secured by complete and thorough washing and scrubbing with chloride of lime or corrosive sublimate solutions combined with free perflation of air.

Disinfection of Ships.—Disinfection on steamships afloat is practically the same as elsewhere, with the exception that the apparatus commonly employed for the purpose of disinfecting bedding and clothing is small and specially adapted for use on board. In ports and harbours the difficulties of disinfection may be overcome by fitting up a hulk or tug with apparatus for disinfection by steam or by the mercuric or formaldehyde spray. All bedding, ship's linen, cushions, curtains, carpets, rugs, personal baggage, and wearing apparel are removed from infected ships by the port Sanitary Authority, and disinfected by steam heat in specially constructed chambers. Leather articles and such as would be injured by moist heat should be treated with mercuric or formaldehyde spray. The disinfection of the ship itself, after disembarkation of the passengers, can be secured by wetting all available surfaces of the vessel excepting cargo, but including hold, saloons, forecastle, decks, &c., with a solution of mercuric chloride or formaldehyde conveyed by rubber hose from the disinfecting hulk or tug. For the disinfection of bilges the best results are obtained by a strong solution of caustic potash or soda, or milk of lime, to saponify the greasy material, followed by crude carbolic acid, izal, cyllin, or kerol all in the proportion of 1 to 20, or live steam when available. If necessary the washing of surfaces may be supplemented by fumigations with chlorine or

formaldehyde vapour. Every opening is battened down, and the process completed in about eight hours.

The possible importation of plague-infected rats by ships has caused the question of ships' disinfection to be much more seriously considered than formerly, as its efficient practice constitutes an important means of defence in port sanitation. For the treatment of a vessel's hold the Clayton method of employing sulphur dioxide under pressure possesses distinct advantages. In the first place, the process of filling the hold with the gas can be carried out simply by gravitation. In the second place, the process is safe. A third advantage is that the gas, unlike carbonic oxide, kills insects. A fourth point is that the gas produced by the Clayton apparatus is a very efficient disinfectant, provided it penetrates. The disadvantages of the process are that it causes serious damage to various articles of food; it is absorbed by articles of cargo and therefore penetrates a cargo mass very slowly. It is thus not nearly so rapid in its action in holds filled with cargo as in empty spaces.

The process of burning sulphur is not applicable to holds full of cargo, on account of fire risks. The proportion of sulphurous acid in the air of a closed space by simply burning sulphur in it is only about 3 per cent., but this is sufficient to destroy all animals, and to produce a fairly satisfactory disinfecting action within a few hours. At least 1½ lb. of sulphur per 1000 cubic feet of space appears to be needed, but the process is tedious and risky. Liquid sulphurous acid gas can be employed for both full and empty holds. It is more expensive than the gas prepared directly by the combustion of sulphur, but it seems to cause less damage to cargo than the Clayton gas or the burning of sulphur. The saving of time, trouble, and risk of fire would probably more than repay the greater cost.

As alternatives to sulphurous acid, the employment of carbonic oxide and carbonic dioxide have been recommended. The former has been used for destroying rats on loaded vessels in Hamburg. The advantages of carbonic oxide are that it can be cheaply and easily made, causes no damage to, and is not absorbed by, cargo. On the other hand, it has no disinfectant action and no effect on insects; as it has no smell, it is dangerous to man unless used with precaution; it can, under certain conditions, form an explosive mixture with air; further, being lighter than air, it does not pass downwards by gravitation. Carbonic dioxide has been successfully used for destroying rats at Marseilles. It has the advantage of not damaging cargoes; it is heavier than air; it is less dangerous to man than the monoxide, since it causes shortness of breath and extinguishes lights before it is dangerous to life. Its disadvantages are that a very large amount of it is needed to kill rats and mice, practically 30 per cent., so that in treating a ship, an enormous amount has to be generated; it is not a disinfectant, and cannot be relied on for killing mosquitoes or other insects.

The choice as to which of these processes is to be employed will depend largely upon the circumstances. If all vessels from plague-infected ports, whether infected or not, are to be treated, the cost of materials and of damage producible by the sulphurous acid will be serious items, so much so that the carbonic oxide would be the more preferable. A skilled staff accustomed to handle this gas would be a necessity. In cases of known infection of vessels, the treatment with carbon monoxide would need to be followed by a separate disinfection process. In view of all the circumstances, the sulphur dioxide process is the more generally useful and, provided the necessary apparatus can be supplied and worked at a reasonable cost, the Clayton method seems to be the best adapted for use in large

British ports. The main doubt is the penetrative power of sulphurous acid from the Clayton apparatus. Possibly this difficulty could be overcome by adding to the sulphur dioxide some 10 per cent. of carbonic oxide; this latter gas has considerable penetrating power, and if mixed with sulphurous acid the risks of accidental poisoning would be small. The diminished proportion of oxygen in the interior of cargo treated by the Clayton process would increase the toxic action of the carbon monoxide on rats, which could thus be destroyed with certainty, while a certain amount of true germicidal action would be secured also. The use of liquid sulphur dioxide has evident advantages on the score of convenience, safety, and absence of capital outlay, but whether it can be used so as to be effective in full holds is doubtful; in empty spaces it is distinctly advantageous.

The Standardisation of Disinfectants.—A very superficial acquaintance with the routine of sanitary work is sufficient to make it clear that the securing of adequate disinfection is by no means a simple operation. Much of this difficulty arises from the fact that there are a number of preparations in the market of considerable popular repute as germicidal agents which are not only worthless but actually dangerous, since their use gives rise to a false sense of security. There exists no official control over the sale of disinfectants, with the exception of those set forth in the Privy Council Orders of July 27, 1900, and June 5, 1902. The first Order permits the sale, without control, of liquids containing less than 3 per cent. of phenol or its homologues as disinfectants, on the ground that such a fluid is not a poison within the meaning of the Pharmacy Act, 1868, In the second Order, it is stated that liquid disinfectants containing scheduled poisons (which for present purposes are practically phenol or its homologues in solutions of more than 3 per cent., and corrosive sublimate) shall be sent out in distinctive bottles. It is clear that these Orders fall little short of placing a premium on inefficiency, and exercise no control over the sale of undoubted efficient disinfectants, such as potassium-mercuric iodide and formaldehyde. This anomalous state of affairs is due probably to the absence of an organised system of standardising disinfectants.

To overcome this difficulty, a number of standards or methods of testing disinfectants have been proposed,* among them being that of Rideal and Ainslie Walker + who have suggested that a bacterial, rather than a chemical determination of efficiency is required, as, although the strength of a preparation of phenol and its homologues can be ascertained with accuracy, there are certain analogous preparations which do not depend on these acids for their germicidal efficiency; they further point out that much depends upon the physical condition in which the re-agent is exhibited, whether in solution or emulsified. The dominant difficulty is the impossibility of reconciling the values given in any two reports on various disinfectants, and this is due to the fact that no two results are comparable unless the details of procedure are identical. The more important factors are time, age of culture, reaction of media, temperature, variations in vital resistance of organisms used, the ratio of culture to disinfectant and the presence or absence of associated organic material. To these must be added the need of a standard control. The standard recommended is pure phenol, and the strength or efficiency of any disinfectant to be

* A useful summary of these standards or methods will be found in the *Public Health Engineer* for June 2, 1906, p. 379.

\+ Rideal and Walker: "On the Standardisation of Disinfectants," *Journ. Roy. San. Institute*, 1903, vol. xxiv. p. 424

expressed in multiples of carbolic acid performing the same work, the ratio so obtained being called the *phenol co-efficient.*

The principle of every method for testing the germicidal power of a disinfectant is to leave bacteria in contact with it for a certain time, afterwards to inoculate the bacteria on suitable culture media, and then, if no growth occurs, to infer that the bacteria have been destroyed. The obvious weak points in this procedure are the possibility of varying amounts of bacteria and disinfectant being transferred during the manipulations; also, no allowance is made for the possibility of organic matter influencing the action of the disinfectant on the micro-organisms. The first two of these difficulties are partially overcome by drying the microbes on threads or garnets; such threads or garnets are immersed in the disinfectant and, after a given time, washed and transferred into suitable media. Obviously these methods are suitable only when dealing with microbial forms, such as spores which will tolerate desiccation. It is true that these highly resistant forms give a clue to the ultimate limits of the germicidal power of a disinfectant, but in practice or the everyday use of disinfectants we have to do rarely with spores, since the majority of the infective agents pathogenic to man are non-sporing. Aware of these drawbacks to the spore-testing method, many experimenters have confined their observations to the estimation of germicidal action of disinfectants on non-sporing bacteria, the principle of their procedure being as explained already. As this course may be pursued in a variety of ways, it is not free from the difficulties which have been enunciated. To a large extent these difficulties have been overcome by the "drop method" of Rideal and Walker * by which, in the hands of competent workers, concordant results are obtained. The principle of the method is well known and may be summarised thus :—a comparison is carried out between the disinfectant which is to be tested and pure phenol; by experiment it is determined what dilution of the disinfectant in question kills a given bacterial culture within the same time limit as a certain dilution of phenol. The quotient of the two dilutions indicates the efficiency of the disinfectant and is called its phenol co-efficient. We have had considerable experience of this method, are familiar with its technique, and found it to furnish results agreeing well with each other, even if different strains of one species of bacteria are used. The most important factor in its successful working we think is temperature, that is, if comparable results are to be obtained. It is noteworthy that different disinfectants have an elective affinity for different species of bacteria, and that the co-efficients of a disinfectant for different species are not always identical, thus, by the drop method cyllin has a phenol co-efficient of 33 against the *cholera vibrio*, of 32 against the *B. pestis*, of 20 against the *B. diphtheriæ*, 14 against the *B. typhosus*, of 11 against *B. tuberculosus* (Klein), of 10 against the *B. dysenteriæ*, and of 9 against the *Staphylococcus pyogenes aureus*.†

The most serious objection to the drop method, as advocated by Rideal and Walker, for standardisation purposes is that it deals with "naked bacteria," that is, the germs are suspended in sterile water. The strength of a disinfectant will necessarily be higher if tested against the naked germ than if organic matter be present, which is always the case in the conditions of everyday practice. This organic matter hinders the penetration of the

* *Op. cit.*

† Some of these figures are from personal observation, others are from a paper in the *Practitioner*, vol. lxix. p. 520.

PLATE XIX

PLAN OF DISINFECTION STATION

A. A. DISINFECTORS

re-agent and in some cases absorbs its chemical energy. The experiments carried out by the disinfectant standardisation committee of the Royal Sanitary Institute,* also those by Hewlett and Kenwood,† by Klein,‡ and by M. Wynter Blyth § afford striking support to this objection.‖ So much so that it becomes a serious question whether, for the routine standardisation of disinfectants, it would not be better so to modify the Rideal-Walker drop method that, in place of testing disinfectants against naked bacteria, the micro-organisms are always suspended in, or mixed with, some organic matter. Whether this be sterile urine, sterile urine and fæces, sterile fæces only, or milk appears to us immaterial so long as the conditions of each test are strictly comparable. Personally, we are disposed to think that sterile emulsions, made by mixing 1 gramme of fresh fæces with 100 cubic centimetres of fresh urine and coarse straining, would constitute an organic medium in which to suspend the particular species of bacteria approximating sufficiently near to the conditions under which disinfectants are used ordinarily. The need for a bacterial standardisation of disinfectants is undoubted, and we think that, in spite of its defects, a modified drop method constitutes at once the simplest procedure ; but it must be borne in mind that no one method of testing disinfectants can indicate their relative values under every possible condition, these must be determined specially for each given case. Where penetrative power has to be tested or is of importance a thread method is indicated, such as that suggested by Delépine.¶ Care needs to be exercised in arbitrarily assigning to disinfectants one figure which may imply their relative or absolute efficiencies ; a safer procedure will be, by a combination of the drop method in water and in organic matter with thread methods, to assign to disinfectants a series of figures which will more or less indicate their relative efficiencies as tested against the particular organism used.

Disinfection Stations.—Every large centre of population ought to possess a properly equipped disinfection station, with suitable quarters for the reception of contacts or others whose personal effects and homes are undergoing disinfection. The value of such a depôt in times of actual or threatened epidemics of small-pox or typhus among slum-dwellers is well known to experienced Sanitary Officers. At all times the dwellers in the poorer districts are careless and pay little attention to advice on public health questions, therefore at epidemic periods the best place for these irresponsibles who have been in contact with the infected is a reception house or disinfection station, which may or may not be made for them a centre of quarantine or place where they can be kept under observation. Even if it be deemed unadvisable to detain contacts or other suspected infectious persons over estimated unexpired incubation periods, the existence of a suitable disinfection station and depôt permits of their being detained at least while their clothing, bedding, and homes are being rendered safe and clean. Whatever plan is adopted, it is desirable that all detained contacts or other persons be treated rationally and sympathetically at the

* *Journ. Roy. San. Institute*, 1906, vol. xxvii. p. 17.

† Hewlett and Kenwood : *Journ. Roy. San. Institute*, 1906, vol. xxvii. p. 1 ; also *Public Health*, 1906, vol. xviii. p. 462.

‡ Klein : *Public Health Engineer*, June 9, 1906, p. 391 ; also *Public Health*, 1906, vol. xix. p. 27.

§ M. Wynter Blyth : *The Analyst*, 1906, vol. xxi. p. 150 ; also *Journal of the Society of Chemical Industry*, 1906, vol. xxv. p. 1183.

‖ W. R. Smith and C. Prausnitz : "Determination of Efficiency of Disinfectants," *Journ. Preventive Medicine*, 1906, vol. xiv. p. 746.

¶ Delépine : "Testing the Germicidal Power of Various Products by the Thread Method," *Journ. Roy. San. Institute*, vol. xxviii. p. 1.

disinfection station so that the depôt be considered a desirable and comfortable refuge during emergencies rather than a compulsory place of detention.

The general arrangements of such a disinfection stat'on are shown in the accompanying plan (Plate XIX.), which is not intended to represent more than the needs, under this head, of an urban Sanitary Authority. It provides three quarters with lavatory and bathroom for detained persons, all these being completely shut off from the rest of the building, which is apportioned to disinfection apparatus, laundry, drying-room, engine-house, van-sheds and quarters for the caretaker. The most notable defect in the plan is the absence of special quarters for a nurse ; whether such a provision is really needed is open to doubt, as the call made on a place of this kind is likely to be intermittent and irregular. Local circumstances and questions of finance will govern naturally the determination of these details, but the recognition of the need and the putting into practical shape of depôts or centres of this kind must constitute in the future a feature of all sanitary administration. In cases where it is reasonable to expect considerable calls for disinfection and reception quarters of this kind, the detention portion might be arranged in flats, each flat being set apart for the accommodation of contacts in different diseases, and entrance to the different flats to be by outside stairs so that there would be no intermingling of contacts. No matter what type of building is adopted, there must be ample bath and water-closet accommodation, with, in addition, the provision of hot and cold water throughout the place. The beds should be of hospital type and the furnishing of the plainest, all carpets and hangings being dispensed with.

LAW RELATING TO DISINFECTION.

The statutory provisions as to the disinfection of clothing, bedding &c., are to be found in section 120 of the Public Health Act, 1875, and sections 5 and 6 of the Infectious Diseases (Prevention) Act, 1890, if such sections of the latter Act have been adopted for the particular district.

The first part of section 120, Act of 1875, provides that " where any Local Authority is of opinion, upon the certificate of its Medical Officer of Health or of any other legally qualified medical practitioner," that any house or articles therein should be disinfected, " it shall be the duty of such Authority to give notice in writing to the owner or occupier " requiring him to disinfect. In each case the Authority must exercise its discretion upon consideration of the certificate, and the notice to the owner or occupier must be given by the Authority itself and not by an officer upon his own initiative.* This is calculated to defeat the object of the section, for in these cases immediate action is needed, yet nothing can be done until the next meeting of the Authority. The same section provides that where the owner or occupier is " unable in the opinion of the Local Authority to carry out the requirements of the section such Authority may, with his consent, cleanse and disinfect such house or part thereof, or articles, and defray the expenses thereof." It is open to doubt whether previous notice in writing, based on a certificate, is necessary in this case. At the time, the point is immaterial, for if an officer of the Authority obtains the owner's consent, the act of disinfection will be done ; but suppose injury be done to clothing so disinfected, can the owner recover compensation in respect of such injury?

* *See* St. Leonard's, Shoreditch *v.* Holmes, 50 J.P. 132.

A recent case * indicates that he can, and that no previous notice in writing is necessary.

The practical difficulty as to immediate action which has been referred to as arising out of the first part of section 120 of the Public Health Act, 1875, is remedied by section 5 of the Infectious Diseases (Prevention) Act, 1890, as it supersedes the former, provided the latter Act has been adopted. Under section 5 of the 1890 Act, it suffices, as soon as the necessary certificate is given, for the clerk to give written notice to the owner or occupier of the house or part thereof that the same and any articles therein will be cleansed and disinfected by the Authority at the owner's or occupier's cost unless he informs the Local Authority within twenty-four hours that he will do it himself to the satisfaction of the Medical Officer of Health within a time fixed in the notice. If this information is not given or, if so given, the disinfection is not carried out within twenty-four hours, the officers of the Authority, under the superintendence of the Medical Officer of Health, shall do it and recover the expenses in a summary manner. If in the opinion of the Local Authority or its Medical Officer, the owner or occupier of such house or part thereof is unable to effectually cleanse and disinfect, the same may without any such notice being given, but with consent of such owner or occupier, be cleansed and disinfected by the officers of, and at the cost of, the Local Authority. By this, the Medical Officer of Health is empowered expressly to judge of the owner's ability to disinfect property. Section 6 of the adoptive Act further allows him, if armed with a general authority to that effect, to require bedding to be handed over for disinfection at the cost of the Authority. Where clothing is removed under this section for disinfection and suffers damage, compensation must be paid ; but if articles are damaged while being disinfected under section 5, no compensation will be payable, the only remedy for the owner of the articles being an action for negligence.

The only provision under which an Authority can destroy infected clothing or bedding is section 121 of the Act of 1875. The section does not require any certificate or notice, but merely says that the "Authority may direct the destruction of bedding, clothing, &c." To provide for certain contingencies arising under this section, the Medical Officer of Health should obtain a general authority to direct the destruction of infected articles, at any rate in cases of serious illness such as small-pox.

* *See* Foster *v.* East Westmoreland Rural District Council, 68 J.P. 103.

CHAPTER XVIII

VITAL STATISTICS

An accurate basis of facts, derived from a sufficient amount of experience and tabulated with proper precision, lies at the very foundation of hygiene, as of all exact sciences. It is desirable, therefore, that all persons interested in sanitary science should know what data are at their disposal, how to collect them, and how to use safely the various facts placed before them. Probably no single cause has contributed more to the attention now paid to questions of Public Health than the careful collection of the statistics of births and deaths, and of the causes of death, which have been collected and published by the Registrar-General's Office during the past fifty years. These collections of figures and facts are usually spoken of as vital or health statistics, because they are so intimately associated with the various problems relating to the health and chances of life of the community. So valuable has been the work done that we are now able to determine with some precision the causes and limits of mortality, and, by the study and analysis of the collection of facts known as vital statistics, to apply them as tests of the health of the communities to which they refer.

The chief vital statistics, bearing upon public health, relate in detail to past and present facts concerning populations, age and sex distribution, births, marriages, deaths, diseases, duration of the hours of occupation and general social conditions, such as the health of each class of the community as judged by the expectation of life at given ages. Statistics of sickness, apart from mortality, have as yet not been attempted, chiefly on account of the difficulty in collecting the data with accuracy.

Population, as the natural basis of all vital statistics, necessarily demands preliminary consideration. Our knowledge upon this point in each place in Great Britain depends primarily upon the census returns which have been made regularly and with increasing care every ten years since 1801. The following table gives the results of some recent enumerations of England and Wales :—

Census.	Population.	Rate of Decennial Increase.	Females per 100 males.	Density	
				Per square mile.	Per inhabited house.
1861	20,066,224	11·9	105·3	344	5·4
1871	22,712,266	13·2	105·4	390	5·3
1881	25,974,439	14·4	105·5	445	5·4
1891	29,002,525	11·7	106·4	499	5·3
1901	32,527,843	12·2	106·9	551	5·2

The chief data collected at each census are the total number of inhabitants in each area, the numbers living of each sex and at certain age-periods, and the numbers employed in certain callings. It will be at once obvious

that the facts relating to the numbers living of each sex and at various age-periods and the numbers employed in certain callings can only be accurately known in actual census years, and from them estimates for intermediate years must be made. An interval of ten years between the takings of the census is now acknowledged to be too long, and it is probable that, if our population statistics are to remain in any way accurate, more frequent enumerations of the people will need to be taken, and even then certain inaccuracies are sure to exist, due chiefly to the still imperfect education of large numbers of householders and heads of families ; these defects of information collected relate especially to occupations and ages. It is remarkable what a large number of people do not know their precise age ; persons generally give their ages in census returns in some multiple of ten. Another source of error and perplexity in all census returns is the too frequent wilful misstatements made by women, owing to their desire, for various reasons, to be thought between 20 and 25 years of age. This is shown by the fact that, in each successive census, the number of women returning themselves as between 20 and 25 is larger than the number of girls returned in the census of ten years before as between 10 and 15 years of age. The former being only the survivors, after the lapse of ten years of these latter, they should of necessity be fewer in number. The male sex is not altogether free from blame in the same matter, though the bias goes in the opposite direction. Thus, men of the poorer classes, who have passed the age of 60, constantly overstate their age for the sake of certain definite advantages, such as getting outdoor relief, or, if entering the poorhouse, gaining some special privileges not granted to their juniors. Some really old people often exaggerate their age in order to appear as centenarians.

In attempting to estimate the population of any given locality for any year intermediate between the collection of census returns, it is necessary to calculate the probable decrease or increase of the particular population by comparing the numbers of the latest enumerations. Thus, say a town had in 1891 a population of 35,626, and in 1901 one of 38,754, and it was required to know its estimated population in June 1906 ; it is only fair in such a case to assume that the 1906 population will be greater than the 1901, and, if we further assume that the increase will be at the same rate as between 1891 and 1901, by taking the difference between the 1891 and the 1901 population and dividing by 10 we get the annual increase of population for that town. Inasmuch as the census is always taken in the first quarter of the year, and we require the population at the end of June 1906, an interval of $5\frac{1}{4}$ years will have elapsed since the last census ; if, therefore, we multiply the annual increase of population, which in this example is $\frac{38{,}754 - 35{,}626}{10} = 312{\cdot}8$, by 5·25, we get an increase of 1642 to be added to the 1901 population, giving an estimated population of 38,754 + 1642, or 40,396 for the middle of 1906.

The foregoing method of calculating an estimated population is fallacious, as it presumes the increase or decrease will be as in an arithmetical progression. The true law of the increase or decrease of a population is that of a geometrical progression, and is very suitably compared to the increase of a sum of money at compound interest. The increase in x years is derived from the increase in one year by multiplying 1 *plus* the annual rate of increase x times into itself. If the increase in one year be 1·5 per cent., 1 becomes 1·015 in one year, and 1·015 multiplied x times into itself will give the increase in x years. To obtain, therefore, the annual rate of increase in x years, the *xth root*, and not the *xth part* of the x rate of increase, must be

taken. If a population of 100,000 in 1901 becomes 101,000 in 1902, it is evident that the 1903 population will be greater than 102,000, for the yearly increase has now to be reckoned upon 101,000, not upon 100,000. If p be the population in any given year, say 1901, and r be the factor of annual increase (in this case $r=1{\cdot}01$), then in 1902 or in one year the population will become $p \times r$, in 1903 or in two years $p \times r^2$, and in n years $p \times r^n$. In the above instance the correct estimate for 1903 would be 102,010, for 1904 it would be 103,030, and so on. In mathematical language the increase is geometrical, not simply arithmetical, and on this assumption the Registrar-General calculates the estimated populations for London and other large towns, as well as for the whole country, for intercensal years. On this basis the calculations are more conveniently performed by logarithms in the following manner:—

Taking the same example as above, in which a town had in 1891 a population of 35,626 and in 1901 one of 38,754, we find the logarithm for the 1901 population, or log 38,754=4·5883165, and deduct from it the logarithm for the 1891 population, or log 35,626=4·5517671; this gives 0·0365494, which is the logarithm of the decennial increase. Dividing this by 10 gives us 0·00365494, or the logarithm of the annual increase, and a quarter of this is 0·0009137, or the logarithm of the quarterly increase. By adding together the logarithm of the 1901 population and five times the logarithm of the annual increase and the logarithm of the quarterly increase we get the logarithm of the mid-year 1906 population, or 4·6075049, which by reference to a set of tables=a population of 40,504, or somewhat higher than the estimation made by that of a simple arithmetical progression.

On the other hand, supposing the census of 1901 to have given a lower figure than that of 1891, the population for any year subsequent to 1901 might be similarly calculated upon an assumption of a uniform decrease. Unfortunately, these assumptions as to a uniform increase or decrease of numbers are largely arbitrary or conjectural, and but rarely agree with the actual facts as found by the next census. As examples we may give the following towns whose enumerated populations differ more than 10 per cent. from the estimated:—Newcastle-on-Tyne (*minus* 10·5 per cent.), Swansea (*minus* 11·9 per cent.), Blackburn (*minus* 15·5 per cent.), Cardiff (*minus* 18·8 per cent.), and Burnley (*minus* 19·5 per cent.). These erroneous estimates of population have obvious vitiating effects on vital statistics. Thus, Burnley, which is an extreme case, had 2214 deaths in 1900, and the death-rate based on the estimated population for that year was 19·6 per mille; when worked out on the enumerated or census population of 1901, it was 22·8 per mille. The only remedy is a more frequent enumeration, as offered by a quinquennial census.

As the Registrar-General has pointed out, the official method of calculating populations by the assumption of an equable rate of growth is only trustworthy in the case of very large communities, where any abnormal increase in one direction is sure to be counterbalanced by an abnormal decrease in another. It is hardly reliable for very small communities, where growth is very often most irregular and spasmodic.

A moment's reflection will show that many circumstances may help to quicken or retard the increase of a population. The increase in any given population may be either *natural* or *actual*. The former is merely the excess of births over deaths, while the latter is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. The facts revealed by the last census, in 1901, showed a decline in the natural increase of population for England and Wales; this

was not due to any increased mortality, but rather to a decline in the birth-rate, which was low beyond precedent. For the whole country the actual increase, as shown by the last census, also showed a decline, due mainly to an excess of emigration over immigration during the last decennium. As a general rule, in towns the *actual* increase is greater than the *natural*, simply because there is a natural tendency for people to migrate from rural to urban districts; and with regard to such local migrations, at present we have no systematic or available record. It is well known that in times when trade is bad in certain localities, a considerable movement of the population occurs to other parts, and *vice versa*.

Apart from the labour entailed in making computations for all districts and towns on the assumption of geometrical increase, the method has the objection that its results, when applied to a number of communities, are not consistent. The method may be, and often is, true for districts, but not necessarily true for the counties or larger areas made up of those districts; and if it is true either for districts or for counties, it is not necessarily true for the whole country. Conversely, if true for, say, England and Wales, it is not generally exact for the counties or the districts. This is illustrated by the following example, quoted by Waters.* A district had a population of 10,000 at one census and one of 11,025 at the next enumeration; on the assumption of a geometrical increase, its population midway between the two censuses was 10,500. Another district had populations of 10,000 and 22,500 at the two enumerations; on the same assumption its population midway between the two censuses was 15,000. The two districts together increased from 20,000 to 33,525 in the intercensal period, and the aggregate of the estimates for the two districts in the middle of the period is 25,500. If the assumption of a geometrical increase be applied to the two districts together instead of to each district separately, the estimate for the middle of the period will be 25,894 and not 25,500. To obtain consistent results in a case like this on the basis of a geometrical increase, we have a choice of two ways of applying the assumption. Either the method of geometrical increase can be applied to each separate district in the country, and the aggregate of the estimates for the districts can be taken then as a fair estimate for the whole country, or it can be applied to the country as a whole, and the resulting estimate divided among the districts.

The assumption of a regular change in the whole population involves smaller risk of error than a similar assumption respecting portions of the population, and has the advantage of being independent of internal migration. Therefore, in the case quoted above, we can proceed to calculate the estimates for the several districts as portions of the total estimate in the following way. Each of the districts having populations of 10,000 at the first census, their respective proportions of the total population was clearly 0·5. At the second census their populations were 11,025 and 22,500, or 0·32886 and 0·67114 were their respective proportions of the total population, or we can say that one district had decreased its proportion by 0·17114 and the other increased its proportion by a similar ratio. If the decrease and increase be supposed to have occurred by arithmetical progression, the proportions at the middle of the period were in one case $0{\cdot}5 - \frac{0{\cdot}17114}{2} = 0{\cdot}41443$, and in the other case $0{\cdot}5 + \frac{0{\cdot}17114}{2} = 0{\cdot}58557$ of the total. The resulting estimates of the population at the middle of the

* Waters: "Estimates of Population." Supp. to the Sixty-fifth Annual Report of the Registrar-General, 1891–1900, Part I. p. cxvii.

period will be 0·41443 of 25,894 for one district and 0·58557 of 25,894 for the other, or 10,731 and 15,163 respectively.

This method may be applied to any number of districts and for any interval, provided the suppositions be made (1) that the population of the whole or combination of the districts changes by geometrical progression, and (2) that the proportion of each district to the whole changes by arithmetical progression. Waters * has further shown that estimates of the populations at any date can be obtained directly from the populations at the two censuses by means of two multiplying factors, and that these factors depend only on the intercensal rate of increase of the total population and the date for which the estimate is required. The factors for the population midway between the censuses are given by the formula $\frac{\sqrt{r}}{2}$ for the first census, and $\frac{1}{\sqrt{r}}$ for the second census, where r is the intercensal rate of the increase of the total population. In the case given already, r is $\frac{33525}{20000}$ or 1·67625, and the two factors work out as 0·64735 and 0·38619. The mid-census population of each of the districts is calculated by multiplying its population at the first census by 0·64735, and its population at the second census by 0·38619. The calculation proceeds as follows:—the first district had a first census population of 10,000, and a second census population of 11,025; multiplying each of these census populations by their respective factors and adding the products together we get 10,731 as the mid-census estimate of population for that district. So, in the case of the second district, where the first census population was 10,000 and the second census enumeration was 22,500, the mid-census estimate is found to be 15,163.

Once the two factors have been calculated, the estimate of population for all districts can be obtained by a simple process directly from their census population. The method is not limited to estimates for a single intercensal period, but can be extended over any number of such periods by further application of the method of finite differences. The extended formulæ and their use will be best understood by a reference to the full text of Waters's original papers.

Although not officially recognised by the Registrar-General, there are several methods of checking estimated populations, which, if used judiciously, are of great value. Amongst such are examinations of inhabited houses as ascertained from the rate-books, and then, assuming the density to remain the same, to multiply the number of inhabited houses by the average number of persons per house. Care, however, must be taken to allow for any marked change in the class of new houses built, whether containing fewer or more occupants than others, and, too, to allow for block buildings, flats, and large hotels, all of which are liable seriously to affect statistical results. Another useful method for checking the calculation of a present population, suggested by Newsholme, may be derived from the birth-rate of a place. It is based on the assumption that the birth-rate remains the same for a series of years as it was found to be at the time of the last census. Thus, in Wandsworth, the average birth-rate for the decennium 1872–81 was 35·68 per 1000, and the number of births in 1881 was 7582, therefore, assuming that 35·68 was the number of births from one thousand of population, 7582 was the birth-rate of 212,500 people. As a matter of fact, the actual census return for Wandsworth, in 1881, was 210,434, an astonishingly close approximation of results.

* Waters: "On the Estimation of Populations," *Journ. Roy. Statistical Soc.*, June 1901.

Age and Sex Distribution.—This is sometimes spoken of as the constitution of a population, inasmuch as it shows the proportion in which males and females, and persons of different ages or of different callings, enter into the composition of the community. These figures and facts are of course only obtained at each census, and generally may be taken to remain constant till the next census. The effect which those facts have upon mortality statistics will be explained later on ; at present, allusion need only be made to the very marked difference which exists in the age distribution between the populations of town or urban and those of rural districts. The 1901 census gives for England and Wales the following age and sex distribution of the population per million persons of all ages :—

Age-periods.	Males.	Females.	Total.	Urban.	Rural.
0–5	57,039	57,223	114,262	114,348	113,978
5–10	53,462	53,747	107,209	105,555	112,760
10–15	51,370	51,365	102,735	101,147	108,397
15–20	49,420	50,376	99,796	101,080	95,489
20–25	45,273	50,673	95,946	100,291	81,370
25–35	76,425	85,154	161,579	167,597	141,390
35–45	59,394	63,455	122,849	124,282	118,039
45–55	42,924	46,298	89,222	88,368	92,086
55–65	27,913	31,828	59,741	56,642	70,139
65–75	14,691	18,389	33,080	29,502	45,080
75–85	5,080	7,010	12,090	10,102	18,758
Over 85	552	939	1,491	1,186	2,514
All ages.	483,543	516,457	1,000,000	1,000,000	1,000,000

This table shows that, as compared with the country districts, in the towns of England and Wales there is a great excess of persons from 15 to 45 years of age, and a small diminution of children between 5 and 15 years of age. The probable explanation of these figures is the persistent immigration of young adults from the country to the urban areas in the one case, and the higher infantile mortality of the towns than of rural districts in the other. The proportion of females to males, of all ages, is much higher in towns than in the country, being 109 to 100 in the former, but only as 101 to 100 in the latter. These proportions are only manifest after the 10 to 15 age-period, when the girls begin to migrate into the towns as domestic servants. The migration of girls into towns is soon followed by that of boys, with the result that the unequal proportion of the two sexes in towns in the 15 to 20 age-period is considerably reduced, and continues to be so during all the more active working ages, or the period from the end of the 25th to the end of the 45th year of life. In the later years of life the disproportion between the sexes in the towns again increases, so much so that in the 55 to 65 years period the women are 20 per cent. more numerous in towns than the men, but only about 5 per cent. more numerous in the country. In the 65 to 75 period the excess is 33 per cent. in the towns and only 7 per cent. in the country ; while in the over 75 years period the excess of women becomes 55 per cent. in the towns and only 15 per cent. in the rural districts. This increasing excess of females in the later age-periods, so far as it is common to both towns and country, is, of course, due to the fact that women are longer lived than men, that is, they survive when the men die off. The greater excess of women over men in towns than in the country is less easy of explanation. It may be due to the fact that men, as they get old, leave the towns, where the struggle for existence is so much the

more keen, and retire into the country more rapidly than do the women ; or it may be due to differences between the conditions of town and country life being more hostile to old men than to old women. Possibly both causes are at work. We know that for some reason or other urban life is exceptionally fatal to elderly men, and that towns offer, even to those in advanced age, more chances of comparatively easy work to women than to men ; hence there is more inducement for women than for men to remain in the towns when they have grown old, especially as town life is much less healthy for men than for women. The practical importance of this question of age and sex distribution in vital statistics will be more apparent when we come to consider the value of death-rates.

Marriage-rates.—These afford a valuable index of national prosperity, and incidentally throw an interesting light on the progress of elementary education. Marriages are usually stated in proportion to the actual population, or the number per 1000 living. This method is fairly reliable in the case of the same community in successive years, but not so for comparing different communities in the same year, because, owing to varying age and sex distribution, the number of marriageable persons must vary considerably in different communities. A more accurate method of estimating the marriage-rate for comparative purposes is to base it on the enumerated or estimated number of bachelors, spinsters, widowers, and widows living at marriageable ages. The number of marriages registered in 1905 in England and Wales corresponds to a rate of 15·3 persons married per 1000 of the estimated population, or 46·6 per 1000 if calculated on the unmarried and widowed population aged 15 years and upwards. This is 2·6 below the average rate of the previous ten years. As a rule, the marriage-rate follows closely the fluctuations in commercial prosperity.

The marriage-rate is always higher in large towns than in rural districts, probably because a large number of young people resort to populous districts, where, owing to the presence of large trades and manufactures, higher wages can be secured, and there they marry. The statistics as to ages at marriage are not perfect, but there is evidence that the mean age at marriage has been gradually rising since 1873. The mean ages of those married in 1905 were 28·56 years for men and 26·38 years for women. The mean age of bachelors who married was 27, of widowers 45·2, of spinsters 25·4, and of widows 40·5 years. Further evidence that marriage is now deferred to a somewhat later period of life than formerly is afforded by the decline in the proportion of under-age marriages. The proportion of marriages of minors, which has shown a nearly unbroken decline since the year 1874, when it stood at 84 per 1000 among husbands and 227 per 1000 among wives, fell in 1905 to 48 per 1000 husbands and 157 per 1000 wives. The proportion of wives who were under age was the lowest in any year since 1851.

The age at marriage, especially the age of the women, is an important factor in controlling the fecundity of marriages, because childbearing is limited practically to between the 16th and 45th years of life. The parents of nearly half the children born are under 30 years of age ; if no women married before 30, the births would be reduced to about two-thirds of their present number, and if the marriage age were postponed to 35, the births would fall to one-third of their present number, and the population would rapidly decline. For not only would the number of births in each generation diminish, but also the interval between the births of successive generations would lengthen, the length of life remaining the same (Farr). It is questionable whether early marriages are really any more fruitful than

later ones, but, even supposing their fertility be identical, the number of children in the late marriages is less, because the generation is longer, and from the fact that many who would have been parents have died before reaching the later age of marriage. In this country the average number of births to a marriage is 4·5.

The latest returns available, or those of 1905, indicate that the men who signed the marriage register with marks instead of writing their names were in the proportion of 16 in 1000, while the similarly illiterate women were 20 in 1000. With the progress of elementary education there has been a continuous diminution in the proportions of both men and women unable to write their names; the proportions in 1905, as compared with those in 1895, showing a reduction of 54 per cent. for men, and of 33 per cent. for women.

Birth-rates.—The Births and Deaths Registration Act of 1874 compels every birth to be registered within forty-two days of its occurrence. In places where the Notification of Births Act, 1907, has been adopted, registration must be within thirty-six hours. The number of births per 1000 persons living, or birth-rate as it is called, in England and Wales, was 27 in the year 1906, or 1·8 per 1000 below the average in the ten years 1896–1905. If calculated on the female population aged from 15 to 45 years, it gives a rate of 109 per 1000. The Registrar-General's returns show that the birth-rate calculated on the total population has decreased during the past 35 years by 21 per cent.; but the rate, calculated on the proportion of total births to the total women living at childbearing ages, decreased in the same period by as much as 27 per cent. Broadly speaking, it may be said that approximately 70 per cent. of the decrease in the birth-rate during the past 35 years, based on the proportion of births to the female population aged 15 to 45 years, results from decreased fertility of married women, which is due in part to changes in their age constitution; about 10 per cent. may be ascribed to the decrease in illegitimacy, and the remaining 20 per cent. is due to the decrease in the proportion of married women in the female population of the conceptive ages. Further, statistics show that the marriage-rate, based on the section of the population in which marriages take place, has fallen continuously, and also that there is a growing tendency to postpone the marriage age, thus curtailing the period within which children can be born.

A decreasing birth-rate is not peculiar to this country; that condition in varying degree being common to nearly all highly civilised communities; it is none the less an economical factor which requires intelligent observation. In this country we have no need for any lessened expansion of the population, as a diminishing or even stationary one may be, and probably is, a grave national danger; but in our own case, so long as our birth-rate exceeds our death-rate in its present proportions (27 to 15·4), we have nothing to fear except lack of employment and want of support for our increasing population. If the actual rate of increase in our population be suggestive of gloomy forebodings to the statistician, would it not be better to dwell less upon the falling birth-rate, but rather dwell more upon the need to check wasteful expenditure of life, and, by so adding to our national income in this respect, secure a more favourable balance. The destruction of infant life in this country is, as we shall note later, enormous, and there can be no doubt that, if we could reduce this loss, we might allow the birth-rate to fall still lower and yet have nothing but gain in every direction.

There is, however, another aspect of the question which needs to be borne in mind, and that is the relative fertility of various classes of the community. Karl Pearson has been very explicit on this point, and goes so far as to say

that the fall in the birth-rate is due to the relative infertility of the most valuable stocks in the race ; he, moreover, attributes to this fact the present dearth of ability, or, in other words, the survival of the less able. Unfortunately, we are not in possession of precise data, but we know in general that the upper classes are less fertile than the middle classes, and these less fertile than the lower classes. A birth-rate of 16 in Mayfair is met with one of 36 in Whitechapel, the figures for the general population being 27. To some this will suggest the need of our attempting to improve the race by attention, not to the quantity, but to the quality of the births. The policy of the future must be to lessen the preventable wastage of young life which now goes on, for the birth-rate will certainly continue to fall as the natural result of human will and the outcome of certain knowledge.

The birth- and marriage-rates are readily found by a simple proportion sum ; thus, if the population of a town be 13,621, and the number of births and marriages during the year are respectively 441 and 215, then $\frac{441}{13,621} \times 1000 = 32{\cdot}3$ birth-rate per 1000, and $\frac{215}{13,621} \times 1000 = 15{\cdot}7$ marriage-rate per 1000. This method of stating the ratio of births, marriages, or deaths in one year, as per thousand persons living in a place, is the most usual and convenient, but occasionally it may be necessary to compare these rates for shorter periods, say weeks, months, or quarters ; in which case it is done in the following way :—Suppose it is required to know the birth-rate during $\frac{1}{n}$ part of a year, then—

$$\frac{\text{Number of births during the period in question}}{\text{Population in the middle of the year}} \times n \times 1000 = \text{birth-rate}$$

of period in question. Taking the preceding example, and required the birth-rate during one week or $\frac{1}{52{\cdot}17747}$ part of a year, during which period ten births have taken place, we get $\frac{10}{13,621} \times 52{\cdot}17747 \times 1000 = 38{\cdot}3$, or birth-rate.

	Birth-rate per 1000 Inhabitants.	Birth-rate per 1000 Women aged 15-45.	Birth-rate per 1000 Married Women aged 15-45.
Kensington . . .	21·8	61·6	215·4
Whitechapel . . .	39·9	172·1	328·3
Percentage excess of birth-rate in Whitechapel over that in Kensington .	83	179	53

When comparing one community with another, to be strictly fair the birth-rate should be calculated on the total population only after it has been reduced to a common or normal constitution as regards sex, age and marriage. This can be secured by calculating the birth-rate on the number of women between 15 and 45 years of age, but this does not take into account the possibility of one community having a large proportion of unmarried women, whose birth-rate would be negligible ; while in another there may be very few unmarried women at these ages. Newsholme * suggests that a statement of the number of legitimate births per 1000 of the number of married women aged 15 to 45 would give a much more accurate measure of

* Newsholme : *Elements of Vital Statistics,* 3rd ed. p. 72.

the fertility of the population. He gives the foregoing example showing the effect of the application of the above three methods of stating the birth-rate in a concrete instance, relating to legitimate births in two metropolitan boroughs in 1891.

It is quite clear we must distinguish between birth-rate and fertility-rate. The first column shows the rates of increase by births, and from a national and economic standpoint this is the final result which is sought. But it does not show, however, how much of the difference in the rates of increase by births in the two districts is owing to differences of fertility. Similarly, the fertility-rates given in the third column can only be accurate for comparing the two communities when of the total wives at the ages 15 to 45 the proportions at intermediate ages are identical in the communities compared, and when there is an equal proportion in the compared communities of newly married women in each of the different age-groups. In actual communities these conditions are never fulfilled. In the later Reports of the Registrar-General, corrections of the crude birth-rates for England and Wales for variations relating to age and married condition are made. Newsholme and Stevenson,* in analysing this question, observe that in ascertaining the true meaning of the great reduction of the birth-rate which has occurred in the last twenty-five years it is necessary to have means for distinguishing between the accidental and the intrinsic causes of change. A step in the right direction is made when the legitimate births are stated in terms of the married women at child-bear ng ages, and the illegitimate births in terms of the unmarried women of the same ages ; but this method fails to correct for the differences of fertility of the various ages comprised in the period 15 to 45. These observers point out that, by calculating standard fertility-rates for given populations and from them corrected fertility-rates, the fertility-rates of different communities can be made directly comparable. They, further, describe a method of obtaining factors, which, when applied to the readily available crude birth-rates, correct completely for both the varying proportion of married women in contrasted populations and for the varying fertility at different periods of married life. The practical importance of these proposals is great, and the original paper, in which full details are given, should be consulted by all interested in this matter.

Period.	Calculated on the Total Population per 1000 Persons.		Calculated on the Female Population aged 15–45 Years. Per 1000.	
	Urban.	Rural.	Urban.	Rural.
1870–72	36·7	31·6	143·1	158·9
1880–82	35·7	30·3	140·6	153·5
1890–92	32·0	27·8	124·6	135·0
1900–02	29·8	26·0	111·4	120·7

It is noteworthy that in 1905 the male births were to the females as 103 to 100, which accords closely with the average proportion in the previous decennium. When we further analyse the birth-rates occurring in the urban and rural districts of England and Wales, as given in the above table, we find various matters of interest.

Taking first the birth-rate based on total population, it appears that during the thirty years 1870–1900, the rate of reproduction in the towns

* Newsholme and Stevenson : "Calculation of Birth-rates," *Journal of Hygiene*, vol. v. p. 175.

was from 15 to 18 per cent. greater than the rate prevailing in the country districts. On the other hand, if the comparison be based on the female population of conceptive ages, we arrive at the important conclusion that the relative fertility of women living in the country was 10 per cent. greater than that of women residing in towns. The comparative rate of decrease of the birth-rate in the town and country areas, if based on the total population, does not show any considerable variation, but is slightly greater in the towns. Whereas, if based on the number of women of conceptive ages in the population, the rate of decrease in the period under review was greater in the country districts than in the towns. This can be accounted for mainly by the continuous migration of young women from rural to town areas, which the census shows to have taken place.

The number of illegitimate children born is diminishing; formerly it was as much as 55 per 1000 births; in 1905 the proportion was 8·2 per 1000 women of conceptive age living, or 40·2 per 1000 births. This illegitimate birth-rate varies much in different districts; thus the registration counties in which the proportion of illegitimate to total births was highest were Norfolk, Nottinghamshire, Shropshire, Suffolk, Denbighshire, and Lincolnshire.

Death-rates.—By the Births and Deaths Registration Act of 1874 all deaths must be registered within five days of their occurrence. In 1906 the deaths registered in England and Wales were in a proportion of 15·4 to 1000 persons living. The death-rate is obtained in exactly the same way as that for births—by multiplying the actual number of deaths from all causes into 1000, and dividing the product by the population; this is known as the general or gross death-rate. In a similar way, as explained above for calculating the weekly or quarterly birth-rate, so is the annual death-rate for the week, month, or quarter obtained.

Thus, take a town with a population of 20,000 and the deaths in any week being 8, the annual death-rate for that week will be 21, or $\frac{8}{20{,}000} \times 52{\cdot}17747 \times 1000 = 20{\cdot}87$. These so-called weekly death-rates are convenient for reports, but are not reliable data on which to compare the relative conditions of places, as much of the mortality often depends upon epidemics, weather, and other causes of a temporary nature. These death-rates, as published for each week by the Registrar-General, must therefore not be regarded as actual rates, but rather as annual rates per 1000, representing the number who would die supposing the same proportion of deaths to population held good all through the year. Their chief value is for contrasting mortality-rates of any given place at corresponding periods of some previous year. The Registrar-General makes his death-rates for each quarter refer to the thirteen weeks most nearly corresponding with the natural quarter; and the quarterly population is obtained by multiplying by thirteen the population of one week. The value of the general death-rate has been much criticised on the ground that it is much influenced by movements of the populations, by the presence of large institutions, such as hospitals, by the age and sex distribution of the population, and by the birth-rate. All this is quite true, but still, if due correction be made, it is probably in the case of large populations the most trustworthy test we have of relative vitality. The corrections most advantageously applied to general death-rates are:—(1) for non-resident or migratory people; (2) for sex and age distribution.

The correction for a migratory population is most difficult to apply, as it is not easy to trace and control the facts relating to visitors and immigrants.

In the case of watering-places and favourite residential towns, corrections in this direction are most important, and are largely made by the officials from materials obtainable from the sub-registrars ; but, even under the best supervision, considerable disturbance and fallacies in the statistics occur. Closely allied to the consideration of migration is the effect which public institutions, such as poorhouses or hospitals, exert on local death-rates, as the disturbance arising from them is due to migration into them from neighbouring districts. To meet this difficulty, the rule is to deduct the deaths of those inmates drawn from outside areas, at the same time adding the deaths of proper inhabitants of the place which may have occurred in other institutions outside the district. In this connection reference may be made to the statistical table A., given on page 17. Each Sanitary Authority in London is supplied quarterly by the Registrar-General with particulars of death of their inhabitants in outlying districts, so that the deaths in all these cases may be apportioned to their proper districts. Unfortunately, such accuracy does not pertain to rural districts, but it is to be hoped, in course of time, even this will be done.

All general death-rates require to be corrected for sex and age distribution.

Sex.—The death-rate among males in England and Wales during 1905 was 16·2, and that among females 14·3 per 1000 living of the corresponding sex. Out of equal numbers living there were 1134 deaths of males to 1000 of females, a ratio corresponding closely to the decennial average. As a class, females live longer than males, the death-rate among the males being uniformly higher than among females, except at the ages between ten and twenty years ; both death-rates, however, are decreasing, owing to the great saving of life in the earlier years of age. Since females live longer than males, it follows that if two towns were in an equally healthy state, but that one of them contained a larger proportion of females than the other, the one with the lower proportion of females would have the higher death-rate.

Ages.—The following table shows the mean annual death-rates in England and Wales, during recent years, per 1000 persons living, at each age-period :—

Age Groups.	All Persons.			Males.			Females.		
	1874-85	1884-95	1894-1905	1874-85	1884 95	1894-1905	1874-85	1884-95	1894-1905
All ages	21·4	19·2	18·1	22·7	20·3	19·2	20·1	18·1	17·1
0–5	63·4	56·8	57·7	68·5	61·6	62·7	58·4	52·0	52·8
5–10	6·5	5·4	4·5	6·7	5·4	4·3	6·3	5·3	4·4
10–15	3·7	3·1	2·6	3·7	3·0	2·4	3·7	3·1	2·6
15–20	5·4	4·4	4·0	5·3	4·3	3·8	5·5	4·4	3·7
20–25	7·1	5·6	4·8	7·4	5·7	5·1	6·8	5·5	4·5
25–35	9·0	7·6	6·9	9·4	7·8	6·8	8·6	7·4	6·1
35–45	12·7	11·5	11·2	13·8	12·4	11·5	11·6	10·6	9·6
45–55	17·8	17·3	17·5	20·1	19·4	19·0	15·6	15·1	14·8
55–65	31·8	31·6	32·8	34·9	34·7	35·0	28·7	28·5	28·5
65–75	65·0	65·4	66·9	69·7	70·4	70·4	61·0	60·4	60·7
75–85	143·1	138·6	142·0	150·8	146·6	146·1	135·4	130·6	130·6
Over 85	311·9	288·3	273·7	327·4	305·8	286·8	296·4	270·8	261·4

The above table shows clearly that there is a great tendency to death among young persons ; this liability to die reaching its minimum from between 10 to 15 years of age, and afterwards steadily increasing through-

out life. There was a remarkable increase of mortality at the advanced ages in 1890–91, due to the prevalence of epidemic influenza.

It follows, therefore, that a town, a large proportion of whose inhabitants were at the most viable age, would have a lower death-rate than a town equally healthy, but in which the ages of the people were less favourable to long life; just as it would be if the one town had a much larger population of females than the other.

Corrected Death-rates.—In order to neutralise the errors in death-rates arising from sex and age constitution of the population, the Registrar-General has devised a method by which they can be corrected. This method, based primarily upon the death-rate of each sex at different ages throughout England and Wales, provides a series of factors by which the recorded death-rates of the great towns can be each multiplied so as to make them comparable with that of England and Wales. By the use of these factors the recorded gross death-rate of any of these towns can be lowered or raised to what it would be if the age and sex distribution of that particular town were the same as that of England and Wales generally. This new rate is called the *corrected death-rate.* The factor employed is practically the expression of the ratio which the recorded death-rate bears to an empirical (arbitrary) *standard death-rate* calculated on the hypothesis that deaths at each age-period were at the same rate as in England and Wales during the decennium 1891–1900, the death-rate at all ages in England and Wales during that period having been 18·194 per 1000. Owing to the proportions of persons of low mortality being excessive in most towns, their recorded death-rates are too low, and in consequence the factor for their correction is in most cases above unity, the exceptions for last year being Norwich, Plymouth, Hastings, Brighton, Southampton, Ipswich, and Yarmouth.

The table below gives these factors for the chief towns as issued by the Registrar-General, along with their recorded and corrected death-rates per 1000 living in 1905:—

Towns in the order of their Corrected Death-rates.	Standard Death-rate.	Factor for Correction for Sex and Age Distribution.	Recorded Death-rate, 1905.	Corrected Death-rate, 1905.	Comparative Mortality Figure, 1905.
Cols.	1	2	3	4	5
England and Wales	18·194	1·0000	15·22	15·22	1000
England and Wales, less the 76 towns	18·85	0·9652	14·80	14·28	938
Seventy-six towns	17·13	1·0621	15·73	16·71	1098
Hornsey	15·96	1·1400	7·57	8·63	567
King's Norton	17·40	1·0456	9·07	9·48	623
Leyton	17·69	1·0285	10·33	10·62	698
Handsworth (Staffs.)	16·53	1·1007	10·07	11·08	728
Walthamstow	17·21	1·0572	10·76	11·38	748
Hastings	18·92	0·9616	12·77	12·28	807
Burton-on-Trent	16·93	1·0747	11·48	12·34	811
Willesden	16·96	1·0728	11·58	12·42	816
East Ham	17·06	1·0665	11·66	12·44	817
Croydon	17·75	1·0250	12·48	12·79	840
Bournemouth	17·22	1·0566	12·34	13·04	857
Northampton	17·50	1·0397	12·55	13·05	857
Brighton	18·46	0·9856	13·49	13·30	874
Wallasey	16·63	1·0940	12·54	13·72	901
Tottenham	16·86	1·0791	12·76	13·77	905
Reading	17·59	1·0343	13·40	13·86	911
Rotherham	17·59	1·0343	13·67	14·14	929
Leicester	17·05	1·0671	13·26	14·15	930
Southampton	18·30	0·9942	14·38	14·30	940

Towns, in the order of their Corrected Death-rates.	Standard Death-rate.	Factor for Correction for Sex and Age Distribution.	Recorded Death-rate, 1905.	Corrected Death-rate, 1905.	Comparative Mortality Figure, 1905.
Cols.	1	2	3	4	5
Ipswich	18·63	0·9766	14·64	14·30	940
Great Yarmouth . .	19·88	0·9152	15·78	14·44	949
Cardiff	16·73	1·0875	13·35	14·52	954
Smethwick . . .	16·63	1·0940	13·31	14·56	957
Aston Manor . .	16·41	1·1087	13·14	14·57	957
Devonport . . .	17·35	1·0486	13·92	14·60	959
Coventry . . .	18·15	1·0024	14·57	14·60	959
York	17·67	1·0297	14·21	14·63	961
Bristol	17·71	1·0273	14·55	14·95	982
Walsall . . .	17·18	1·0590	14·14	14·97	984
Wolverhampton . .	17·59	1·0343	15·00	15·51	1019
Norwich . . .	19·05	0·9551	16·25	15·52	1020
Derby	16·88	1·0778	14·56	15·69	1031
Halifax . . .	16·79	1·0836	14·62	15·84	1041
London . . .	17·31	1·0511	15·08	15·85	1041
Grimsby . . .	16·99	1·0709	14·82	15·87	1043
West Ham . . .	17·01	1·0696	14·84	15·87	1043
Gateshead . . .	17·26	1·0541	15·50	16·34	1074
Plymouth . . .	18·66	0·9750	16·82	16·40	1078
Birkenhead . . .	17·07	1·0658	15·40	16·41	1078
Barrow-in-Furness .	16·01	1·1364	14·58	16·57	1089
Leeds	16·68	1·0908	15·25	16·63	1093
Hull	17·75	1·0250	16·26	16·67	1095
Bradford . . .	16·46	1·1053	15·23	16·83	1106
West Bromwich . .	18·04	1·0085	16·74	16·88	1109
South Shields . .	17·19	1·0584	16·08	17·02	1118
Portsmouth . . .	17·72	1·0267	16·61	17·05	1120
Newport, Mon. . .	16·84	1·0804	15·77	17·04	1120
Bolton	16·09	1·1308	15·07	17·04	1120
Nottingham . . .	17·27	1·0535	16·50	17·38	1142
Birmingham . . .	16·91	1·0759	16·16	17·39	1143
West Hartlepool . .	16·57	1·0980	15·85	17·40	1143
Swansea	16·96	1·0728	16·66	17·87	1174
Stockport . . .	16·84	1·0804	16·73	18·08	1188
Newcastle-on-Tyne .	16·89	1·0772	16·80	18·10	1189
Huddersfield . .	16·96	1·0728	16·97	18·21	1196
Bury	16·25	1·1196	16·33	18·28	1201
Sheffield . . .	16·88	1·0778	17·00	18·32	1204
Blackburn . . .	16·09	1·1308	16·21	18·33	1204
Warrington . . .	16·89	1·0772	17·02	18·33	1204
Rochdale . . .	16·45	1·1060	16·68	18·45	1212
St. Helens . . .	16·79	1·0836	17·05	18·48	1214
Stockton-on-Tees . .	17·35	1·0486	17·79	18·65	1225
Burnley . . .	16·14	1·1273	16·56	18·67	1227
Salford . . .	16·47	1·1047	16·94	18·71	1229
Sunderland . . .	17·64	1·0314	18·62	19·20	1261
Preston . . .	16·63	1·0940	17·91	19·59	1287
Tynemouth . . .	17·62	1·0326	19·31	19·94	1310
Manchester . . .	16·32	1·1148	17·99	20·06	1318
Bootle	16·50	1·1027	18·20	20·07	1319
Oldham	16·18	1·1245	17·98	20·22	1329
Wigan	16·58	1·0973	18·62	20·43	1342
Rhondda . . .	16·54	1·1000	19·05	20·96	1377
Liverpool . . .	17·00	1·0702	19·63	21·01	1380
Hanley	16·67	1·0914	19·31	21·07	1384
Middlesbrough . .	16·71	1·0888	20·96	22·82	1499
Merthyr Tydfil . .	17·16	1·0603	22·11	23·44	1540

If the corrected death-rate in each town be compared with the corrected death-rate at all ages in England and Wales, taken as 1000, it gives a number known as the *comparative mortality figure*, as shown in the last column of the preceding table. These figures may be expressed in another way,

by saying that after correction has been made for differences of age and sex distribution, the same number of people that gave 1000 deaths in England and Wales in 1905 gave 930 in Leicester, 1093 in Leeds, and 1287 in Preston. Or we can say that in 1905 the corrected death-rate for the whole of England and Wales was 15·22 ; and the recorded death-rate for Blackburn is 16·21, with its factor for correction as 1·1308. Then $16{\cdot}21 \times 1{\cdot}1308 = 18{\cdot}33$ as the corrected death-rate for Blackburn, and $\frac{18{\cdot}33}{15{\cdot}22} \times 1000 = 1204$ as its figure of comparative mortality.

As an example of the method of calculating a standard death-rate, the following table, which gives the necessary data in a particular instance, namely, of the town of Huddersfield, is quoted from Newsholme's *Elements of Vital Statistics* :—

Ages.	Mean Annual Death-rate in England and Wales, 1881-90, per 1000 living at each Age Group.		Population of Huddersfield in 1891.		Calculated number of Deaths in Huddersfield.	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5	61·59	51·95	4,551	4,785	280	249
5	5·35	5·27	4,691	5,081	25	27
10	2·96	3·11	5,113	5,165	15	16
15	4·33	4·42	4,905	5,549	21	25
20	5·73	5·54	4,541	5,461	26	30
25	7·78	7·41	7,466	8,834	58	65
35	12·41	10·61	5,576	6,265	69	66
45	19·36	15·09	3,944	4,649	76	70
55	34·69	28·45	2,393	3,017	83	86
65	70·39	60·36	1,128	1,590	79	96
75 and upwards	162·62	147·98	250	466	41	69
Totals			44,558	50,862	773	799
			95,420		1572	

Combined Death-rates.—A very frequent source of error in vital statistics is made in calculating the mean death or other rate of two populations or communities ; these are often spoken of as *combined death-rates*. The error usually arises from failing to take into account the proportion which the two populations or groups bear to one another. Thus, suppose two towns each contain 30,000 inhabitants, and have respectively mortalities of 22 and 16, their mean or combined death-rate would be $\frac{22+16}{2}$ or 19. But suppose one of the towns has 42,000 inhabitants and the other 18,000, and have respectively the above mortalities, their combined death-rate will then not be the mean of their two separate death-rates, but as follows :—

One town of 42,000 people with a death-rate of 22 per 1000 = 924 deaths.
„ 18,000 „ „ 16 „ = 288 „

or 60,000 people give 1212 deaths

and $\frac{1212 \times 1000}{60,000} = 20{\cdot}2$, the true combined death-rate per 1000.

Influence of Birth-rate on Death-rate.—With regard to the influence of the birth-rate upon the death-rate much controversy has prevailed. To a great extent this has been unnecessary, and has arisen from a misconception as to the true meaning of the relation between the birth- and death-rates. Practically, the birth-rate affects the death-rate only in so far

as it alters the age constitution of the population. If we imagine a population in which there has been a high birth-rate for one or more years, it is clear such must contain a larger proportion than usual of young children, and inasmuch as the death-rate of young children is higher than that of all others except the aged, the general death-rate of that population will be raised ; but this condition is to a large extent counterbalanced by the fact that a high birth-rate implies the presence in that particular population of a large proportion of persons of the childbearing age, that is, of an age-period when the mortality is unusually low. So, again, if the high birth-rate be continued for any length of years, it means not only a large proportion of children and of persons at reproductive ages, but also of young adults, among whom a low rate of mortality also prevails. In the same way a continuously low birth-rate may bring about a low death-rate, but, if it continue to operate, it will lead to an accumulation of persons over 15 years of age and be followed by a steady rise in the death-rate, however excellent the sanitary conditions of the district may be ; when the authorities doubtless will be as eager as they are now unwilling to have the recorded death-rate "corrected."

The real influence of the birth-rate upon the death-rate, therefore, is not one which can be well expressed as a low birth-rate causing a low death-rate, or a high birth-rate producing a high death-rate, but rather that the average age of a population governs the death-rate, and that the lower the mean age of the living, the lower should be the death-rate, and, by inference, that the death-rate really controls the birth-rate, because the lower it is, the more chance is there of there being a large proportion of persons at the child-producing ages. If a high death-rate follows a high birth-rate, it reasonably suggests an excessive infantile mortality ; very often low death-rates and low birth-rates co-exist, but it must not be supposed that the one is always necessarily caused by the other.

Relation of Density to Mortality.—The influence exerted by density of population on mortality and death-rates has long been recognised. The density may be either expressed as so many persons to a square mile, or as acres to a person, or we may state the distance which would separate each individual from his next neighbour if the whole population were spread as uniformly as possible over the surface of the country. Two methods are commonly adopted for calculating the degree of aggregation of population :—(1) the number of persons living to each square mile of area is stated ; and (2) the average number of acres occupied by each person in the population is stated. The gradual increase of density of population in this country is shown in the following table :—

Date of Census.	1831	1841	1851	1861	1871	1881	1891	1901
Persons per square mile .	238	273	307	344	390	445	499	551
Acres per person . .	2·69	2·34	2·08	1·86	1·64	1·44	1·29	1·15

Attempts have been made to express the relations between density of population and mortality by means of a mathematical formula, but so many variable conditions are involved that any such rule must be of very limited practical application. The general increase of mortality with increase of density is well defined in the Table on p. 786, and may be accounted for by the increased overcrowding incidental to the growth of large towns. The figures quoted refer to England and Wales for the decennium 1891-1900. From the returns of the Registrar-General it is noticeable that while the

mean density of the English population rose from 499 in 1891 to 551 in 1901, the death-rate fell from 18·73 to 18·19 per 1000. The same returns show, further, that whereas in 1871–80 there were 101 districts with an aggregate population slightly exceeding two millions that had mean annual death-rates below 17 per 1000, there were 387 districts in 1891–1900 with more than eleven millions of persons that had death-rates below that limit. On the other hand, in 1871–80 there were over seven millions of people, living in 82 districts, where the rate exceeded 23 per 1000; in 1891–1900 only 14 districts with a population of rather more than one and a half millions were subject to these high death-rates. These comparisons are based on the crude death-rates, but if we compare the mortality in districts grouped according to their corrected death-rate, we find that in 1871–80 no district had a corrected death-rate lower than 12 per 1000, while in the recent decennium there were 27 districts with an aggregate population of 305,363 persons where the mortality fell below that limit. It further appears that the number of districts with corrected death-rates between 12 and 13 per 1000 rose from 33 in 1881–90 to 112 in 1891–1900. The other end of the table shows equally improved conditions of mortality, the number of districts in 1881–90 with rates above 23 per 1000 having been 41, with over five millions of inhabitants, and in the recent decennium only 20 districts with less than half that population.

Number of Districts.	Area in Acres.	Population.	Deaths.	Density as Persons to a Square Mile.	Mean Crude Death-rate.	Mean Corrected Death-rate.
27	1,434,417	305,363	43,374	136	14·20	11·63
112	6,654,217	1,675,837	252,254	161	15·05	12·54
92	6,985,414	2,848,795	440,496	261	15·46	14·52
56	3,607,345	2,576,691	429,546	457	16·67	16·53
31	1,597,845	1,839,178	324,429	737	17·64	17·58
40	1,813,474	3,690,975	665,908	1,303	18·04	18·53
31	1,185,809	3,159,033	587,988	1,705	18·61	19·42
21	612,983	2,240,001	436,896	2,339	19·50	20·37
18	401,707	2,776,506	561,075	4,429	20·21	21·56
13	277,734	2,119,515	438,624	4,884	20·69	22·36
6	122,320	801,663	176,777	4,194	22·05	23·48
5	166,769	762,259	177,546	2,925	23·29	24·33
5	67,761	791,926	195,953	7,480	24·74	26·54
4	3,313	287,624	93,959	55,563	32·67	34·82

In attempting to appraise the true value of density upon mortality the most reliable index is the number of persons per room, and wherever we find overcrowding in houses there is invariably a concomitant high infant mortality and total death-rate. Any increased density of population gives rise to filth conditions, to the more rapid spread of infectious diseases, phthisis, accident and other objectionable conditions, the outcome of co-existent poverty and occupation. It is probably by and through these, rather than from mere overcrowding, that density of population in any way influences the death-rate of a community. The practice of building back-to-back houses, formerly so prevalent in Lancashire and Yorkshire, and without provision for thorough ventilation, illustrates very clearly the evil effects of crowding populations.

Urban and Rural Mortality.—Closely connected with the influence of density of population upon mortality is the question of the respective death-rates in urban and rural districts. Taking two selected groups of counties as representing respectively the urban and rural areas of England

and Wales, the Registrar-General shows the corrected death-rates for urban counties in 1891–1900 to be 20·34 per 1000, while that for rural counties is but 14·88.* The following Table, compiled from official sources, puts the matter in a slightly different way:—

Period.	Persons to a Square Mile in England and Wales.	Annual Deaths to 1000 Persons living in			Deaths in Town Districts to 100 Deaths in County Districts in equal numbers living.
		England and Wales.	Town Districts.	County Districts.	
1851–1860	344	22·2	24·7	19·9	124
1861–1870	390	22·5	24·8	19·7	126
1871–1880	445	21·4	23·1	19·0	122
1881–1890	499	19·1	20·3	17·3	117
1891–1900	551	18·19	20·8	17·2	120

The death-rate is evidently diminishing in both urban and rural areas, but more rapidly in the former than in the latter, so that the difference between them grows less. Between 1851–60 and 1891–1900 the urban death-rate has declined 15·7 per cent. and the rural death-rate 13·5 per cent. This does not, however, represent the exact facts, as only crude death-rates have been used in comparison, and these overstate the mortality of healthy districts and understate that of unhealthy districts (Newsholme). The increased excess of the urban over the rural death-rate in 1891–1900 was in part due to the high mortality from diarrhœa, a disease affecting town in greater degree than country populations. The rates in the same period, however, in the rural districts had been unusually high, doubtless on account of epidemic influenza, thus reducing the difference between urban and the rural rates, so that the ratio of urban to rural mortality only reverted to its normal figure.

As Newsholme has pointed out, the true difference between urban and rural mortality is greater than is shown in the preceding table, if due allowance be made for sex and age distribution. There is in the town districts a much larger proportion of females, a larger proportion of adults of both sexes in the prime of life, and a much smaller proportion of very aged persons. "There is a slight counterbalancing influence of a large number of infants in towns, but these, as we have already seen, are followed by an increase of young adults, and, therefore, apart from any excess of infant mortality, ought not to raise the general death-rate." It is chiefly after density has reached a certain degree of intensity that it begins to exert an appreciable effect. As Ogle points out:—"In crowded communities it may be a matter of vital importance whether there are 500 or 1000, or 2000 or more persons living on a square mile, yet it can scarcely make any difference, as far as health goes, whether in rural districts there be two acres or three acres on an average to each inhabitant. The differences in the death-rates in these sparse populations are determined by other conditions than aggregation." The extent of the correction required on these accounts may be gathered from an example. In 1893 the urban death-rate was 20·2; the rural death-rate 17·4. Owing, however, to the great differences of age and sex distribution of the respective populations, the urban death-rate ought, with equal healthiness, to have been nearly 12 per cent. lower than the rural death-rate, instead of being, as it was, 16 per cent. above it. These aspects of the value of the death-rate as the barometer of public health are of particular interest

* Supplement to the Sixty-fifth Annual Report of the Registrar-General in England and Wales for 1891–1900.

in regard to current suburban death-rates. Thus, in 1904, the crude death-rate among the 88,142 estimated residents in the metropolitan suburb of Hampstead did not exceed 9·3 per 1000, and after correction for the age and sex constitution of the population was only raised to 10·5, or barely half the corrected rate of the metropolitan borough of Shoreditch. It is a fact, however, that no less than 27 per cent. of the enumerated female population of Hampstead at the last census were domestic servants, whereas in Shoreditch only 2·4 per cent. of the females were domestic servants. These considerations suggest that death-rates for suburban districts, even if corrected for sex and age constitution, should not be accepted as altogether trustworthy indications of the relative health conditions of their populations without due allowance for other disturbing factors.

Ages at Death.	London.			Rural Counties		
	Legitimate.	Illegitimate.	Total.	Legitimate.	Illegitimate.	Total.
Under 1 week	23·5	42·4	24·1	25·3	35·7	26·0
1–2 weeks	6·1	11·5	6·4	5·6	11·0	5·8
2–3 ,,	6·0	10·2	6·2	5·5	9·2	5·6
3–4 ,,	5·0	8·5	5·1	4·0	5·7	4·1
1–2 months	14·3	40·2	15·1	12·8	23·4	13·4
2–3 ,,	10·8	32·3	11·6	9·5	16·5	9·9
3–4 ,,	10·0	24·9	10·6	8·1	14·4	8·4
4–5 ,,	8·4	18·1	8·7	6·7	11·0	6·9
5–6 ,,	7·5	17·4	7·9	5·7	10·2	5·9
6–7 ,,	7·8	16·2	8·1	5·6	9·9	5·8
7–8 ,,	7·5	13·8	7·7	5·2	8·4	5·4
8–9 ,,	7·6	11·9	7·8	5·1	5·7	5·1
9–10 ,,	6·9	10·4	7·0	4·8	7·2	5·0
10–11 ,,	7·0	8·3	7·0	4·6	5·6	4·6
11–12 ,,	6·8	10·8	7·0	4·0	4·5	4·0
Total under 1 year	135·2	276·9	140·3	112·5	178·4	115·9

Infantile Mortality.—The calculations of infant and child mortalities demand special remark; particularly as it is by no means uncommon to find them worked out on the population, or on the number of deaths at all ages. The infantile mortality is the annual number of deaths of infants under one year of age to every thousand births during the same year. The greatest care should be given to child mortality, or to the death-rate of those under five years of age, as it constitutes an important and instructive index of health conditions. In 1906 the infantile death-rate or proportion of deaths of infants under one year of age to registered births in England and Wales was 133 per 1000, as compared with 150, the mean proportion in the preceding ten years. The importance of this subject cannot be overestimated, as it constitutes the master key of all public health work. Unfortunately, the loss of life under this head is enormous, so much so that it really is a blot upon our modern civilisation. According to the returns furnished by the Registrar-General relating to the year 1905 for England and Wales, out of every 1000 children born alive, there died from all causes 66·6 under three months old, 24·7 from three to six months old, 36·8 from six to twelve months old, or a total of 128·1 under one year of age, while another 44·6 per 1000 died before they were five years of age. These rates differ widely in different counties and towns, the general rule being that the infantile mortality is lowest in purely agricultural areas, and highest in the mining districts and in those with textile industries. But a high infant

death-rate does not necessarily imply a high tendency to death among the rest of the population, as many towns which have a notoriously high infantile mortality have at the same time a low general death-rate.

The chief causes of infantile mortality, common to every locality, are briefly :—premature birth, illegitimacy, congenital defects, inexperience and neglect of mothers, industrial conditions, improper food, and overlaying. Infant mortality is more particularly influenced by the prevalence of epidemic diarrhœa, and by epidemics of measles or whooping-cough.

The effects of illegitimacy on infant life are well shown by the Table on page 788, prepared in 1904 for the information of the Committee on Physical Deterioration. The figures refer to 1902, but as they deal with 238,000 births and 31,800 deaths they are sufficiently extensive ; the ratios are expressed as mortality rates per 1000 births at the several age-groups under one year.

Taking together both legitimate and illegitimate children we find that at all ages beyond the first week, urban conditions are much more destructive to infant life than are those of the country areas. Probably, however, the most dominant factors in the causation of infantile mortality are the industrial employment of married women, overcrowding, and a high birth-rate. Reid * inquired into the mortality of children under one year of age in three classes of artisan towns in Staffordshire in relation to the employment of women in factories. His statistics cover twenty years, and, as will be seen from the following Table, show a very regular association of high infantile mortality with the industrial employment of married women. The figures are all the more valuable as the other general conditions of the towns were similar.

	Towns with many Women engaged in Industrial Work.	Towns with fewer Women engaged in Industrial Work.	Towns with practically no Women engaged in Industrial Work.
Census population, 1901	147,281	198,955	182,864
Infantile mortality, 1881–1890	195	166	156
,, ,, 1891–1900	211	177	167
,, ,, 1901–1904	193	156	149

When we come to look into the actual causes of death, we find that to "wasting diseases" are attributed quite 30 per cent. of the deaths from all causes occurring in the first year of life, the majority of which are those of infants within three months of birth. Of the deaths from wasting diseases nearly half are referred to atrophy or debility, and almost as many more to prematurity, the children possessing at birth a vitality too feeble to support life apart from the mothers ; lung diseases contribute 17 per cent., and diarrhœal diseases 18 per cent. of the total mortality ; convulsions appear as the cause of about 11 per cent., and tuberculous diseases of another 6 per cent. The Registrar-General's returns show that in the course of the last twenty-five years there has been a decline in the mortality from the chief epidemic infantile diseases, with the exception of measles and diarrhœa, and also a decline in the mortality from bronchitis, laryngitis, meningitis, convulsions, atrophy, and debility. On the other hand, there has been a rise in the mortality ascribed to pneumonia, rickets, measles, diarrhœa, prematurity, and congenital defects. In the two latter instances, the differences are probably due to more accurate certification of the cause of death.

Among the conditions leading to a high infantile mortality and to what-

* Reid : *Brit. Med. Journal*, 1901, vol. ii. p. 410 ; also *Lancet*, 1906, vol. ii. p. 426.

ever degeneracy may prevail in certain sections of the community, a prominent place must be assigned to overcrowding. It is a fact that for every person who fifty years ago lived in a town, there are three so situated at the present time. Residence in towns too often involves overcrowding; and that overcrowding only too frequently means poverty, intemperance, crime and domestic mal-hygiene is well known. It is not so much the aggregation itself as these other factors which are associated with it that produce the high mortality, whether of infants or others, in our great towns or other thickly populated areas. We have laid stress, previously, on the view that the true density that must be considered is the number of persons to each room, not the number of persons on a given area.* The census standard for overcrowding is anything over two persons to a room. The following table, by Shirley Murphy † relating to London, is most instructive on this point: but if any doubt can exist as to the relationship existing between the two circumstances the following facts are of interest:—

Proportion of Total Population living more than Two in a Room in Tenements of less than Five Rooms.	Total Deaths under 1 Year of Age during the Period 1891–1900.	Deaths under 1 Year of Age per 1000 living at Age 0–1, during Period 1891–1900.
Districts with under 10 per cent. . .	13,533	142
„ „ 10–15 per cent. . .	56,208	180
„ „ 15–20 „ . .	42,158	196
„ „ 20–25 „ . .	36,521	193
„ „ 25–30 „ . .	23,219	210
„ „ 30–35 „ . .	22,580	222
„ over 35 „ . .	16,800	223

Of the county boroughs in England and Wales, the three with the greatest proportion of their population living under overcrowded conditions are:—Gateshead with 34·5 per cent., Newcastle-on-Tyne with 30·4 per cent., and Sunderland with 30·1 per cent. The average infantile mortality of these three towns for the decennium 1893–1904 was:—Gateshead 174, Newcastle 173, and Sunderland 175.

The relationship between a high birth-rate and high infant mortality is shown by some figures given by Divine,‡ the influence, if any, is probably an indirect one as the outcome of social grading, but the facts are certainly interesting and concordant, whether we take counties, towns, or districts of large towns. The following Table is one of several given by Divine in illustration of this point; we think the figures should be interpreted with due regard to other circumstances than mere high birth-rate:—

Rate per 1000 Persons living, 1903.	St. George's, Hanover Sq.	Kensington.	Hackney.	Stepney.	Whitechapel.
Marriage-rate . .	21·3	18·4	14·8	15·1	14·4
Birth-rate . .	17·5	20·3	26·9	32·3	36·3
Infantile mortality .	141	145	128	208	194

Causes of Death.—It is not sufficient to know the death-rate of a community; it is necessary to know and inquire what rates the different

* Newsholme: *Elements of Vital Statistics*, 1899, p. 165.

† Shirley Murphy: Evidence before Interdepartmental Committee on Physical Degeneration, App. to Report, p. 52.

‡ Divine: "Some Social Factors in the Causation of Infantile Mortality," *Lancet*, 1906, ii. p. 142.

causes of death give when the deaths are distributed to their several classes. Although the death-rates obtained from registrars are principally derived from certificates signed by either doctors or coroners, and, as such, should be clear statements of the precise cause of death, still even now the cause of death in many cases is both vague and ill-defined. Each year, however, shows improvement in this direction, with the result that the registration of causes of death is becoming more and more accurate and complete.

The Registrar-General adopts eight chief divisions of diseases each with subsections. The first group comprises the febrile constitutional or zymotic diseases; the remaining groups include five which are headed parasitic, dietetic, constitutional, developmental, and local diseases, together with "violence," and, finally, "ill-defined and non-specified causes." It is not an ideal classification and hardly abreast of modern medical knowledge, but suffices for the present. It is important to note that the term *zymotic death-rate* which is in general use does not apply to the mortality from the whole zymotic group of the Registrar-General, but to the death-rate from what are called the eight principal zymotic diseases, namely, small-pox, measles, scarlet fever, typhus, enteric, whooping-cough, diphtheria, and diarrhœa, including cholera; to these should be added tubercular diseases and rheumatic fever as belonging to the infective class.

Causes of Death.	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905
Small-pox	17	*nil*	8	5	3	10	75	23	15	4
Measles	570	408	419	314	394	276	392	274	363	324
Scarlet fever	177	147	113	117	119	133	148	125	111	122
Typhus	2	2	1	1	1	1	2	2	1	1
Enteric fever	166	156	181	198	173	155	126	100	93	89
Whooping-cough	429	367	323	318	356	313	297	285	352	255
Diphtheria	291	246	243	292	290	273	236	182	170	160
Diarrhœa	563	868	955	971	728	914	418	542	867	595
Phthisis	1,303	1,336	1,311	1,330	1,333	1,264	1,233	1,203	1,236	1,140
Rheumatic fever	87	81	77	83	86	86	84	71	70	72
Pneumonia	1,146	1,198	1,125	1,250	1,374	1,147	1,407	1,220	1,281	1,311
Erysipelas	36	33	31	38	38	35	39	32	36	37
Cancer	762	785	799	826	829	842	843	872	877	885
Diabetes	74	78	82	85	86	91	84	85	93	93
Alcoholism	71	77	78	90	113	96	84	76	70	65
Influenza	122	195	330	389	504	174	223	189	168	204
Bronchitis	1,535	1,503	1,479	1,606	1,692	1,365	1323	1,112	1,246	1,139
Bright's disease	260	264	271	289	306	297	279	284	295	282
Cirrhosis of liver	122	133	132	142	144	132	123	117	117	117
Heart disease	1,449	1,493	1,483	1,574	1,576	1,478	1,460	1,406	1,467	1,535
All causes.	17,053	17,379	17,518	18,249	18,228	16,909	16,230	15,418	16,239	15,227

The zymotic death-rate or death-rate from special febrile diseases is an important fact to be noted among all communities, as it furnishes a very popular standard as to their general healthiness. But it will be readily understood that it is liable to great fluctuations according to the greater or less prevalence of one or other of those diseases, with the result that a so-called mean zymotic death-rate is often of little value. Thus, say in a given community the zymotic death-rate be excessive owing to the epidemic prevalence of the two zymotic diseases, measles and whooping-cough, owing to these diseases not being either usually or truly dependent upon defective sanitary conditions, their excessive prevalence, as evidenced by an increased zymotic death-rate, furnishes less clue as to the health condition of the community than would an equally high zymotic mortality rate, due to such

diseases as diphtheria or enteric fever, which are more directly the expression of faulty sanitary states.

The annual death-rates *per million* persons living in England and Wales, from the chief causes of death during recent years, are given in the Table on page 791.

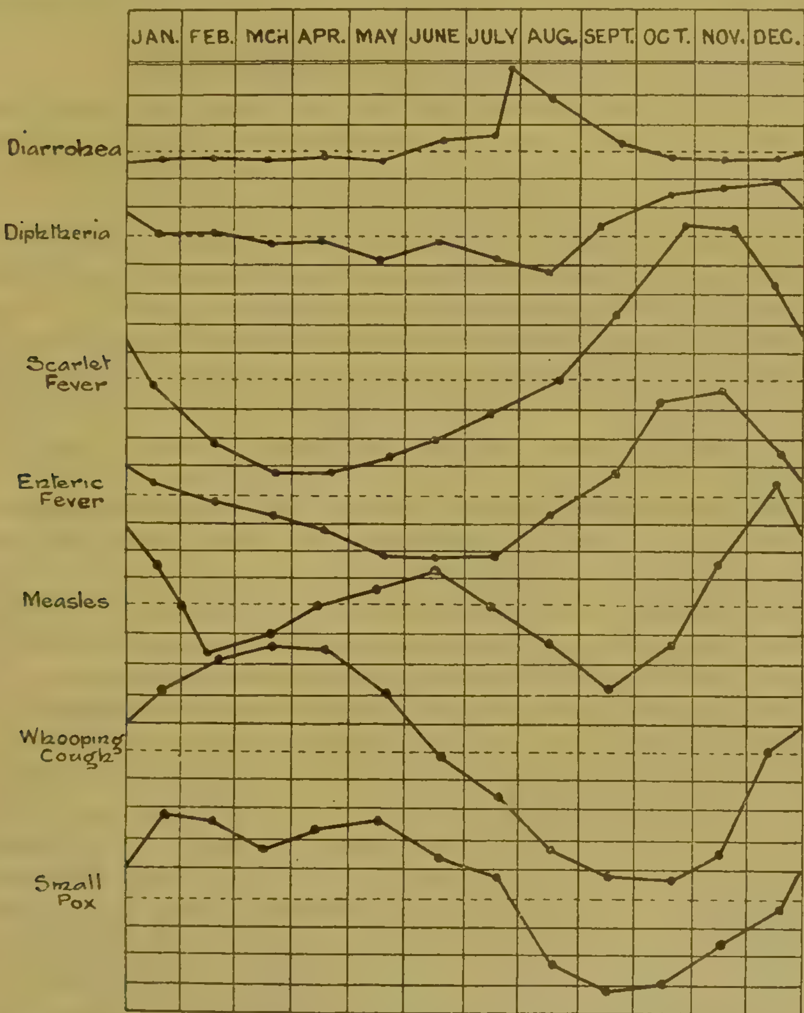
The foregoing Table indicates that, in regard to certain well-defined diseases, the death-rate has changed in the direction of increase or decrease. The increase in mortality is manifest in respect of cancer, diabetes, diarrhœa, and influenza. Measles and whooping-cough show a high average mortality, with little tendency to decrease, but these diseases have no demonstrated relation to insanitary conditions, and as yet have not been seriously combated either by hospital isolation or disinfection.

A decrease is manifest in the mortality from scarlet fever, enteric fever, diphtheria and phthisis. The reduction in regard to the first three is real, and mainly attributable to improved sanitation. Phthisis has been undoubtedly lessened by better drainage and ventilation, but improved diagnosis is probably responsible for the transfer of some cases to the category of other respiratory diseases.

Other influences which have an important bearing upon the mortality of certain diseases are sex, age, and occupation. The mortality among women appears to be higher than among men for such diseases as rheumatism, anæmia, chlorosis, erysipelas; while for affections connected with childbirth, it is, of course, limited to the female sex. On the other hand, men die more than women when affected with such diseases as syphilis, diabetes, rickets, typhus, meningitis, and hydrophobia.

The influence of age upon mortality rates is very marked in certain diseases. Thus, phthisis or consumption is at its lowest prevalence between the ages of 5 and 12, but increases up to 47 years of age, after which it lessens. Small-pox mortality is highest in the first and twenty-fifth years, while diarrhœa, whooping-cough, measles, and diphtheria all have their highest death-rates during the first few years of life. Cancer is a disease which appears rarely to affect the young, but tends to increase after 28 years of age. Diseases connected with the heart and circulatory system increase in their mortality-rates from birth upwards. The total death-rate, and the death-rates from affections of the nervous system, lungs, and bladder, all appear to be at their lowest between the tenth and fifteenth years of life. The true influence of sex and age are not well shown by mere death-rates, as the numbers living diminish as age advances. Further, the variations in incidence and severity, according to sex and age, are not always parallel, in fact often inverse, as in enteric and scarlet fever. The best evidence as to incidence of disease is available from notification returns in respect of both age and sex, while the proportion of deaths to attacks will be available from registration data. Probably in respect of no age-period is the incidence of disease more instructive than it is upon early infancy. Of the common infectious diseases, measles becomes serious at the early age of six months and continues to be so until the second year. The mortality from scarlet fever as well as from diphtheria first becomes excessive at the age when children begin to come in contact with one another, the rate of mortality from these diseases being approximately constant from the end of the first to the end of the fifth year. From whooping-cough, however, the mortality is greatest among infants under one year of age, falling with great rapidity in each succeeding year of life; the highest mortality is experienced between the ages of six and twelve months. At the age-period of from three to six months, diarrhœal diseases, to the causation of which hand-feeding so largely

contributes, account for more than one-third of the total mortality at that age; in a less degree the death-rate from diarrhœa continues heavy to the end of the second year of life. The mortality from what are called "wasting diseases" affects chiefly the first three months of infancy, more than four-fifths of the deaths thus returned being those of children at that age. Tuberculous diseases are most fatal to children under one year of age, the incidence being somewhat higher in the second three months than in other



Seasonal Curves of Mortality (London). Mean of 40 years, except Diphtheria (20 years), and Enteric Fever (12 years).
Each division corresponds to 10 per cent, above or below the mean annual mortality indicated by the dotted line.

FIG. 160.

parts of the first year; at subsequent ages under five years the mortality decreases steadily. To "convulsions" a much greater mortality is referred in the first three months than at any subsequent age. Both pneumonia and bronchitis are responsible for a serious loss of life up to the end of the second year, the mortality from bronchitis decreasing during the first year while that from pneumonia increases. Finally, at least one out of every five hundred children born meets its death by suffocation in bed.*

Seasonal Incidence of Disease. It is a matter of common knowledge that most diseases have a fairly constant relation to season, and

* Sixty-seventh Annual Report of the Registrar-General for England and Wales.

their seasonal mortality presents characteristic curves of variable range. We must confess to great ignorance as to the causes at work, but many diseases appear to have an obvious relation to heat and cold ; thus diarrhœa and other digestive affections of young life have a summer maximum, while in deaths from diseases of the lungs, heart, and kidneys there is a winter maximum. In this country, enteric fever, scarlet fever, diphtheria, erysipelas, puerperal fever, and rheumatic fever have their maximum about November ; on the other hand, deaths from phthisis, small-pox and whooping-cough have a spring maximum. Measles has two maxima in June and December with two minima in September and February. (Fig. 160.)

There are also characteristic seasonal curves of mortality from all causes at certain ages. Under one year of age there is an exaggerated maximum from the end of June to the middle of August, due to the prevalence of diarrhœal diseases ; the lowest death-rates among this age-group occur in April and May. From one to five years, the principal maximum is in March, owing to the seasonal prevalence of whooping-cough and measles, but there is a rise also in July and August due to diarrhœal affections. Above five years of age to late adult life, the mortality shows only a slight excess in midwinter and a slight falling off at midsummer. It is noticeable, too, that as the years of age increase so a sensitiveness to cold is manifested by a wider range of seasonal curve ; in early life, there is a similar sensitiveness to heat.

Age-incidence of Mortality from Certain Diseases.—This subject has been much discussed during recent years, and presents certain features of interest to those concerned in public health work. For much valuable information we are indebted to the Reports of Sir Shirley Murphy to the London County Council and, the more the facts are collated, it is increasingly evident that notable changes have occurred during recent years in the age-incidence of several important infective diseases. If the mean death-rate at each age in a whole period of time be taken, say during the last forty-five years, this constitutes a standard ; and if the death-rate at each age in each quinquennial or decennial period be stated as a percentage above or below the mean of the whole period, the excess or defect of the death-rates at these ages in each period will form a curved line above or below the mean. It is obvious that any deviation from a straight line represents variations in the age-incidence of mortality.

Taking *diphtheria* as an example, we find that the curve of mortality for this disease in 1860–65, which was a period of epidemic prevalence, shows a marked convexity downwards, the ages 4, 5–10, and 10–15 being the then lowest points in the curve. The next three quinquennial periods are periods of decline of prevalence, but the decline was less manifest at the ages mentioned than at ages below and above them, so that any line representing mortality for the period 1876–80 is almost a straight line. In the following four quinquennial periods there was an increase of prevalence, the increase being at much the same ages, the result being that the line for 1896–1900 becomes a curve with the convexity upwards, or the exact converse of 1860–65, and having the ages 4, 5–10, and 10–15 the three highest points in the curve. In the last quinquennium, 1901–05, the death-rate at all ages has fallen, so that the line has now become almost straight again. There has, therefore, been a change in age-incidence for diphtheria which is suggestively rhythmical, and it will be interesting to see whether in 1906–10 and 1910–15 there will be a reversion to the curve types of 1866–70 and 1871–75, with convexity downwards.

The statistics of *scarlet fever* show a story of decline during practically

the whole period for which the figures are available ; there is, however, a greater tendency for the mortality curves to become flatter in the later quinquennia than in the earlier. The figures for 1861–65 show greater relative incidence on the ages 4, 5-10, 10–15, and 15–20 than those for any other period, but we have to remember that the intervals between epidemic prevalences of scarlet fever are probably longer than in the case of diphtheria, therefore the time for the minimum incidence on the ages mentioned has not yet come ; otherwise, a depression in the curve at those ages ought to have been manifest in the last two quinquennia, unless the greater aggregation of children at those years of age has obscured the effect.

The figures for *measles* tell much the same story. In 1861–65, the mortality was exceptionally high at ages 2, 3, and 4 ; since then, with a decline in mortality the line becomes nearly flat. The case of *whooping-cough* closely resembles measles, the curve which can be traced for the figures of 1861–65 becomes flattened out in subsequent periods.

The facts in regard to *enteric fever* are interesting because, while there has been a decline in the death-rate at all ages during the past forty-five years, with very slight exception in 1896–1900, there has been an increasingly greater relative incidence on the age-period 25–35, and on the ages which immediately precede and follow that age-period. Although it is conceivable that the age-incidence of mortality from this disease would be affected by changes in the opportunity for infection to reach man by particular channels, still, as Shirley Murphy says, there is the possibility that this change is a natural variation, particularly if we remember that, in spite of a decline of mortality from diphtheria at all ages, that disease manifested an increase of incidence on age-periods 4, 5–10, and 10–15.

The natural behaviour of *small-pox* in respect of age-incidence is difficult to follow, owing to the disturbing effect of vaccination. It is, however, interesting to contrast the incidence on the age-period 0–5 and 5–10 in the two epidemic periods 1851–60 and 1871–80 with that during the last decennium. In the absence of epidemic prevalence, the age-incidence mortality lines lose their curvature and become nearly straight in these later years.

The statistics relating to *phthisis* show a notable general decline of mortality from this disease; this has been especially marked, during recent years, at the younger ages. The probable explanation is the successive additions by birth of a more resistant race.

Cancer mortality presents certain changes in age-incidence which are interesting, but only explicable on the hypothesis of change in nomenclature. The incidence on ages below 25 has fallen markedly, but the actual incidence on ages 25–35 has, however, remained practically constant for the last fifty years.

If we examine the figures of deaths from *all causes*, the most prominent feature is the tendency for the mortality of the first year of life to be maintained in greater degree than that of subsequent ages. This is largely due to the mortality from measles and whooping-cough being so high in the first year of life. Without losing sight of the effect which change of nomenclature and better diagnosis must have on the statistical returns of mortality, there can be little doubt that, in the case of the infectious diseases, variations in the age-incidence of mortality occur as a natural phenomenon not improbably due to variation in virulence, and affected also by such influences as differences in opportunity of acquiring infection, and the proportion of persons at the several ages rendered immune by attack in antecedent periods. There is still much to be learnt regarding these facts, and until they relate

to an extended series of years it is unwise to dogmatise , for the present, it suffices to indicate the lines on which inquiry should be made.

Occupation.—The investigations of Ogle and Arlidge, and more recently those of Tatham, have thrown considerable light upon the influence which occupation has upon mortality. Some callings are much less favourable to health than others; some again, while being relatively healthy, are dangerous from the explosive nature of the materials employed. The chief circumstances which render certain employments more or less hurtful to health are:—bad ventilation and overcrowding of workrooms; exposure to weather, or extremes of heat and cold; inhalations of vapours, gases, or metallic, mineral and organic dust; overstrain and mental anxiety; also temptations to intemperate habits. Many difficulties and fallacies underlie all comparative statistics of class mortalities, unless due allowance be made for the age at which such employments are followed, as well as the question of the class of person actually engaged, and the importance of differentiating between employer and employed. Thus, a death-rate of 10 per 1000 among factory girls aged 15–25 in a town where the general death-rate was 22 would be very high, since that for females at that age-period is about 5. This precaution is sufficient when, in the absence of anything specially unfavourable to health in the occupation, any excessive mortality must be ascribed to insanitary surroundings or irregular habits. As Farr says, "It would be obviously unfair to expect that all trades could be rendered equally healthy; and when a certain amount of danger to life or unhealthiness is unavoidable, the death-rate should also be compared with that of some other group of workers in the same or similar industry, thus giving a practicable as well as an ideal standard."

Again, the healthiness or unhealthiness of an occupation may be obscured by the fact that those who follow the several industries do not start on equal terms as regards health. A weak, weedy lad will not become a navvy, but a tailor or shopman by preference. The occupations demanding great muscular strength and activity to some extent, then, consist of picked men. So, again, there are some callings only attainable late in life, while, on the other hand, some are only suited to young persons, who, after a few years, seek more lucrative employments. In all these cases the mean age at death is delusive. Most females follow their employments only until by marriage they cease to be self-supporting; consequently, the mean age at death of female clerks, domestic servants, and shop assistants is valueless. To give that of ladies' maids as 36 and of nurses as 60, or to say that the mean age at death of a judge is 68 and that of a solicitor is 50, is merely an abuse of statistics.

The Table on page 797 shows the comparative mortality and death-rates as gathered from Tatham's figures for the years 1890–92, which is the latest period for which an analysis is available.

The comparative mortality figure is derived in this way. During the years 1890, 1891, and 1892, 1000 deaths occurred annually among 61,215 men between 25 and 65 years of age. Of the 61,215 men aged 25–65, at the census of 1891 there were:—

22,586 in the age group	25–35 years.
17,418 „ „	35–45 „
12,885 „ „	45–55 „
8,326 „ „	55–65 „

By applying to these four numbers the corresponding rates of mortality for any occupation, the number of deaths is ascertained which would occur among 61,215 men engaged in that occupation. This number is the com-

parative mortality figure. Thus, in the case of clergymen, the age-group 25–35 years, with a death-rate of 4·23, yielded 95·53 deaths; the age-group 35–45, with a death-rate of 5·18, yielded 90·22 deaths; the age-group 45–55, with a death-rate of 10·52, yielded 135·55 deaths; the age-group 55–65, with a death-rate 25·35, yielded 211·06 deaths; consequently the total deaths in the population of 61,215 men, distributed as above, were 532·36, viz., there were 532·36 deaths as compared with 1000 deaths, the general male mortality in the same population with identical distribution.

Occupation.	Ages.				Comparative Mortality Figure.
	25 Years.	35 Years.	45 Years.	55 Years.	
Clergyman, priest, minister	4·86	4·23	5·18	10·52	533
Barristers, solicitors	5·32	10·67	17·72	34·50	821
Physician, surgeon, general practitioner	6·69	14·92	21·04	34·16	966
Commercial traveller	6·09	12·62	21·41	39·28	961
Carman, carrier	9·31	16·82	28·01	50·44	1284
Bargeman, lighterman, waterman	9·94	16·71	24·44	44·17	1199
Farmer, grazier, farmer's son	4·29	7·03	11·20	23·97	563
Agricultural labourer	5·54	9·14	13·56	24·83	666
Fisherman	9·13	10·60	18·61	25·65	845
Innkeeper, publican, spirit, wine, and beer dealer	15·21	23·32	34·84	53·18	1642
Innkeeper, servant, &c.	15·06	24·52	35·24	52·68	1659
Grocer, &c.	5·40	8·62	14·34	24·92	664
General shopkeeper	8·89	14·03	19·92	32·59	973
Printer	9·10	14·40	21·56	43·39	1096
Butcher	7·53	15·66	22·65	43·32	1096
Corn miller	5·07	9·33	18·90	38·83	845
Hatter	6·96	15·35	24·75	43·90	1109
Baker, confectioner	6·49	11·00	22·18	35·45	920
Tailor	6·86	13·67	21·98	37·59	989
Hairdresser	9·41	15·01	23·28	39·03	1099
Shoemaker	7·66	11·35	19·85	35·25	920
Tanner, fellmonger	5·78	6·40	18·69	32·78	756
Tool, scissor, file, saw, needle maker	8·36	18·38	32·93	57·52	1412
Currier, &c.	6·79	12·67	22·16	40·62	998
Blacksmith, whitesmith	5·80	10·81	20·74	39·45	914
Copper, lead, tin, zinc, &c., dealer and worker	7·43	13·98	24·55	46·02	1123
Bricklayer, mason, builder	6·55	13·45	22·04	40·23	1001
Carpenter, joiner	5·78	9·36	17·19	32·15	783
Plumber, painter, glazier	7·04	14·79	25·13	45·58	1120
Wool, worsted manufacturer (West Riding)	6·99	11·99	20·58	43·76	996
Cotton, flax, linen manufacturer (Lancashire)	7·13	13·38	25·11	55·06	1176
Wool, silk, cotton, &c., dyer, printer	10·90	16·14	28·05	57·95	1370
Potter, earthenware, &c., manufacturer	8·19	19·58	42·97	75·13	1706
Coal miners	6·29	9·63	19·42	43·79	935
Tin miner	8·06	14·32	33·20	66·09	1409
Glass manufacturer	11·32	17·88	32·14	60·79	904

Inn-servants, innkeepers, and brewers all have an excessive mortality, chiefly due to intemperance, but a large proportion of this class must be of temperate habits, as the comparative mortality figure for recognised intemperate persons is, according to Neison, 3210. Publicans and innkeepers show also the highest mortality from gout and urinary diseases, with the exception of occupations dealing with lead. Plumbism, as well as alcoholism, would appear to be a cause of some forms of heart disease, as diseases of the circulatory system are most fatal among brewers, publicans, costermongers, cabmen, fishermen, painters, plumbers, filemakers, and potters. Nervous diseases give rise to a high mortality among those addicted to intemperance, and appear to be most fatal in the same occupations as are

associated with a marked mortality from alcoholism. The same is the case with diseases of the liver, while suicide also has a fairly close relation to intemperance.

Respiratory diseases, especially phthisis, cause a high mortality among the debilitated, and those exposed to the weather, to impure air, and to certain forms of dust. For these reasons we find a high mortality figure among costermongers, tailors, drapers, cutlers, filemakers, potters, printers, wool- and cotton-workers, and in some miners, such as the Cornish miners. Coal-miners, as a class, have a relatively low mortality figure, probably due to the fact that coal-mines are well ventilated, and that the nature of the employment excludes weakly persons. Lead-poisoning is prevalent among printers, earthenware-makers, painters, plumbers, glaziers, and file-makers. The two latter callings show also an extremely high mortality from renal diseases. The high mortality of printers is due less to plumbism than to phthisis. Butchers show a high mortality, which is apparently due to excessive indulgence; the same remark applies to commercial travellers. The shopkeeper class have a relatively low mortality; among them grocers suffer much less than drapers from phthisis and respiratory diseases, but more from diseases of the circulation, and slightly more from alcoholism and suicide. The clergy enjoy the lowest mortality, being closely pressed in this respect by gardeners, farmers, and agricultural labourers; the latter appear to suffer much from phthisis and respiratory diseases. Farmers have a somewhat high mortality from gout, alcoholism, and liver disease. Fishermen appear to have a low mortality from diseases of the nervous and respiratory systems, but suffer largely from accidents.

Sickness Rates.—Our information on this point is somewhat unsatisfactory, as the materials are wanting for a complete study of the amount of illness in the community. What statistical evidence we have is drawn from the experience of friendly societies, certain industrial organisations, the police, the navy, and the army. All these, however, are more or less selected bodies, and cannot be regarded as fairly representing the general population. The following figures have been obtained from, and are based upon, the experience of certain friendly societies, more particularly the Manchester Unity of Oddfellows and the Foresters:—

Ages.	Number of Years of constant Sickness corresponding to one Annual Death.	Annual Average Amount of Sickness per Head, in Weeks.	Average Duration of each Illness, in Weeks.	
			Males.	Females.
10–20	2·47	0·75	3·43	3·30
20–30	2·53	0·93	3·80	3·90
30–40	2·17	1·00	4·74	5·20
40–50	2·45	1·80	5·58	5·80
50–60	2·64	2·60	7·80	7·00
60–70	4·00	4·36	9·54	9·50
70–80	5·53	7·50	12·12	12·60
Over 80	4·80	10·50	10·00	11·00

These figures indicate that after mid-life the average duration of each illness increases, and with it the "expectation of sickness" and the proportion of number of cases of illness to each death. On the basis of these data it may be calculated that, inasmuch as in 1905 there were in England and Wales 520,031 deaths, there were 1,469,362 constant sufferers from sickness, and nearly 2,000,000 sufferers from such illness as would require medical

relief, or throw the members of friendly societies on their funds. The economic loss to the community represented by this amount of sickness is enormous; and, assuming that a large proportion of it is preventable, the necessity of still further improving the sanitary condition of the people is manifest.

Statistical Evidence of the Health of Communities.—In attempting to judge the health of a community by statistical evidence, the greatest importance is attached to the following points, namely, the total corrected death-rate, the zymotic death-rate, and the infant mortality. All these have been discussed, and the various sources of error connected with them explained. Equally significant with the zymotic death-rate and the infant mortality is the phthisis death-rate, which, if excessive, indicates dampness of soil, unhealthy workrooms, or overcrowding of tenements. The death-rate from respiratory diseases, other than phthisis, is also important. But for precise purposes, such as life assurance, more exact guides to health conditions are needed; these have reference to means of measuring the mean duration of life and are best furnished by a life-table.

Life-tables.—Farr called a life-table a *biometer*, because it really represents a "generation of individuals passing through time," and measures the probabilities of life and death of this generation at birth, and of survivors at each successive age-period, until the whole generation is extinct.

In order to construct a life-table it is necessary to have (1) particulars from a census return of the number, age, and sex distribution of a population; (2) returns of deaths for one or more years among this same population, grouped in the same ages or age-periods as have been adopted for stating the census population. A separate table is required to be constructed for each sex, and for this reason the death returns must be distinct for the two sexes.

A life-table can be constructed for either annual or quinquennial or decennial intervals; in most tables an annual interval is adopted for the first five years, and, after that, five-year periods are taken. This kind of table and those with annual intervals are often spoken of as extended life-tables and involve an enormous amount of work; for the needs of Medical Officers of Health and local requirements shortened tables, as suggested by Hayward,* are sufficient. The first step is to ascertain from the census returns a statement of the total lives at risk and the number of deaths in the 5- and 10-year groups of ages; if a shortened table only is to be prepared, these data will suffice, but if an extended table is desired at annual intervals the corresponding numbers for individual years of life must be found. This can be done in two ways, (*a*) by a method of finite differences applied to the logarithms of the figures representing population and deaths at the beginning and end of each age-period—this is known as the analytical method and involves complex calculations; † (*b*) by what is called the graphic method—this is more easy of application and requires less mathematical knowledge than the analytical.‡ According to Newsholme, the results by this method are just as accurate as by the analytical, except for the first five years of life,

* Hayward: "On Local Life-tables by Short Methods," *Public Health*, July 1898; *also* "An Improved Method of Constructing Shortened Life-tables," *Journal of Hygiene*, vol. v. p. 185.

† For details, consult Farr's No. 3 Life-table, p. xxv.; *also see* Decennial Supplement to Registrar-General's Report, 1891, Part I.

‡ King: "On the Graphic Method of Constructing a Life-table," *Journal of Institute of Actuaries*, October 1883; *also consult Elements of Vital Statistics*, by Newsholme, 3rd ed. p. 266.

when, owing to certain disturbing factors, the analytical or some special method should be used.*

Having, by one or other of the foregoing procedures, obtained the mean population or the number of lives at risk at the centre of each year of life, and the number of deaths in the corresponding years of life, then, by dividing the former into the latter we obtain the rate of mortality per unit of population, better known to actuaries as the *central death-rate*, because it represents the rate at which people are dying in the centre of a given year. Let this be expressed per 1000, and call it D. These deaths may be assumed to be evenly distributed over the whole age-period, so that half the deaths will occur in the first portion of the period, and the other half in the second portion; and the ratio of the final to the initial population is $\frac{1000-\frac{1}{2}D}{1000+\frac{1}{2}D}$ which, when simplified, becomes $\frac{2000-D}{2000+D}$. This ratio is practically identical with the probability of living through one year, or p_x equals $\frac{\text{number of survivors at end of year}}{\text{number living at beginning of year}}$.

For the construction of a hypothetical life-table, let us suppose that the mortality among infants in a given population is 100 for every 1000. It will be at once evident that, if there be 1,000,000 babies born and living at the commencement of a given year, these will be reduced to 900,000 in the course of the year, and this number will commence the second year. Presuming that the data show that the death-rate among children in the second year of life is as high as 50 per thousand living, then, applying the foregoing formula, we get $\frac{2000-50}{2000+50}$ or $\frac{1950}{2050}$ or 0·951219, and the 900,000 children at the beginning of the second year are reduced to 900,000 × 0·951219, or 856,097 at the beginning of the third year. In the same way, knowing the death-rates for the third, fourth, and fifth years of life, the actual numbers of children surviving at the end of those age-periods is calculated. Suppose now by the end of the fifth year only 650,000 survive out of the original million, and we propose to continue constructing the life-table for quinquennial or five-year periods in place of annual intervals. The calculation is practically the same, substituting for the death-rate of each year the death-rate for each quinquennium. Presume the death-rate among persons aged 5–10 years to be 7, then applying the formula for the reduction of the population during this five-year period, we get $\left(\frac{2000-7}{2000+7}\right)^5$ or 0·965632, and at the end of this quinquennium, or by the end of the tenth year, the 650,000 will be reduced to 650,000 × 0·965632 = 627,660. This calculation can be repeated for each five-year period until there are no more survivors left.

Such an ideal life-table will consist of a series of columns, in the first of which will be entered the various years of life or age-periods headed by the symbol x.

The second column would be marked D, or as it is sometimes written m_x. The entries in this column would be obtained by dividing the deaths during each year or age-period by the corresponding mean population, and represent the rate of mortality.

From the entries in the second column, those of the third or p_x column

* Newsholme, *op. cit.*; *also* Newsholme and Stevenson: "The Graphic Method of Constructing a Life-table," *Journal of Hygiene*, vol. iii. p. 297.

would be obtained. These represent the probability of living one year for each age or age-period, as calculated from the formula $p_x = \frac{2000 - D}{2000 + D}$.

The next column, l_x is obtained by multiplying the number living at the immediately preceding year by p_x. The entries in this column will represent the number surviving at each successive age, or, in other words, l_x represents the number who reach the precise age x.

The next column required in a life-table is one showing the mean number living in each year of life, and technically called P_x. Thus the mean number living in the tenth year $= \frac{l_9 + l_{10}}{2}$.

The next column in the table is known as the Q_x column. The number opposite any age in this column is the sum of all the numbers in the P_x column from that age to the end of the table, that is, until all the lives become extinct; and it shows, therefore, the aggregate number of years which the persons at each age in the table will live.

The last column is that marked E_x; in it, opposite each age, is placed the mean after lifetime, or expectation of life at each age. This is obtained from the formula $E_x = \frac{Q_x}{l_x}$.

The following table represents the headings of a typical life-table, prepared in accordance with the foregoing principles; it will serve to show a complete view of the results obtainable from a life-table. Each year of age should be inserted to make it complete, but in order to economise space, the intermediate years have been omitted.

Age or Age-period. x.	Annual Mortality per Unit at Age x. D or M_x.	Probability of Living one Year from each Age. p_x.	Number Born and Living at each Age. l_x.	Mean Population in each Year of Age. P_x.	Years of Life Lived at Age x and upwards. Q_x.	Mean after Lifetime at each Age x. E_x.
0	0·18326	0·83212	511,745	456,820	20,426,138	39·41
5	0·01369	0·98640	370,358	367,672	18,410,252	49·71
10	0·00563	0·99438	353,031	352,007	16,608,936	47·01
15	0·00519	0·99482	344,290	343,415	14,866,429	43·18
20	0·00832	0·99171	333,608	332,231	13,169,656	39·48
25	0·00920	0·99084	319,442	317,892	11,536,677	36·12
35	0·01105	0·98901	288,850	287,229	8,492,601	29·40
45	0·01554	0·98458	253,708	251,763	5,774,489	22·76
55	0·02485	0·97644	209,539	206,984	3,447,708	16·45
65	0·04698	0·95410	150,754	147,315	1,631,508	10·82
75	0·10391	0·90122	75,777	72,012	491,685	6·49
85	0·21966	0·80208	16,877	15,151	63,030	3·73
95	0·42035	0·65265	833	678	1,806	2·17
105	—	—	4	3	5	—

On this basis a number of life-tables have been constructed, the more important being the following:—"English Life-table No. 1," based on the population enumerated in 1841, and the deaths registered during the same year: * "English Life-table No. 2," based on the population enumerated in 1841 and the deaths registered in the seven years 1838–44; † "English Life-Table No. 3," based on the census returns of 1841 and 1851 and the deaths registered in the seventeen years 1838-54. This was published with a large number of Insurance Tables founded on it as a separate volume in 1864. "English Life-table No. 4" was founded on the mortality

* *See* the Fifth Annual Report of the Registrar-General, 1842.

† The Table for Males is in App. to Registrar-General's Twelfth Annual Report, that for Females in the Twentieth Annual Report, 1857.

in the ten years 1871–80; * and "English Life-table No. 5" on the mortality of the ten years 1881–90.† The "English Life-table No. 6" has recently been issued, being based on the death-rates for the ten years 1891–1900.‡ In addition to these six tables, three other official life-tables have been constructed on the mortality experienced in selected Healthy Districts; the first was based on the mortality in 63 districts which showed, during the decennium 1841–50, a mean annual death-rate not exceeding 17 per 1000 persons living; § the second was based on the mortality in 263 Healthy Districts whose death-rate in 1881–90 did not exceed 15 per 1000 living,|| while the third is based on the mortality of 260 districts whose death-rates in the ten years 1891–1900 did not exceed 14 per 1000.¶

Besides these official life-tables, a number of smaller tables have been constructed, such as the following:—The "Upper Class Experience Table" constructed by Ansell from data collected by him as to men of the upper and professional classes.

The "Healthy Males Table," based on the experience of the principal insurance offices.

The "Clerical Experience Table," based on data respecting over 5000 clergymen living between 1760 and 1860.

The "Brighton," "Manchester," "Glasgow," and "London" Life-tables, prepared by the Medical Officers of Health of those respective towns on the basis of the census of 1891 and death-rates of recent years.

Hayward's "Shortened Life-table" for the Haydock Urban District.

The Table on the opposite page gives a portion of Tatham's "English Life-table No. 6" as issued in 1907.

Having stated the data on which a life-table is based, and described the method of its construction, we are in a position to study the life-history of the persons to which it has reference. The essential points for such a study are the three following:—

(*a*) *The probability of living a given period for each age-period* in the two sexes separately.—This is commonly written p_x, and equals, as we have already seen, $\frac{\text{number of survivors at end of period}}{\text{number living at beginning of period}}$. Thus, by the accompanying English Life-table, at birth the probability of a male child living one year is $\frac{828,136}{1,000,000}$, or, the certainty of surviving to the end of the first year of life bei g taken as unity, the probability of his dying during the year is $\frac{1,000,000-828,136}{1,000,000} = 0{\cdot}271864$. At 25, the probability of a male living five years by the same life-table is $\frac{673,200}{693,894}$, and the probability of his dying during the quinquennium is $\frac{693,894-673,200}{693,894}$ or 0·02982; and so on.

(*b*) *The number of survivors out of* 1,000,000 *children born* of each sex, at each succeeding year, or quinquennial period of life, until the whole

* *See* Supplement to Forty-fifth Annual Report of Registrar-General, pp. vii. and viii., 1886.

† *See* Part I. of Supplement to Fifty-fifth Annual Report of Registrar-General, pp. ix. to xx. 1897.

‡ *See* Part I. of Supplement to Sixty-fifth Annual Report of Registrar-General, pp. xlii. to xlvii. 1907.

§ Farr: *Philosophical Transactions of Royal Society of London*, 1859; *see also* Supplement to Thirty-third Annual Report of Registrar-General.

|| Supplement to Fifty-fifth Annual Report of Registrar-General, 1897, pp. clxxxiv. to cxciv.

¶ Tatham: Supplement to Sixty-fifth Annual Report of Registrar-General, 1907, pp. lii. to lx.

number becomes extinct by death.—The following Table starts with a million boys and a million girls assumed to be born at the same time, and shows how many survivors there would be at each successive period. Thus, of 1,000,000 males born, 530,888 are still alive at the end of fifty years from birth; and of 1,000,000 females born, 580,320 survive to the same age.

Age. x.	Chance of Living One Year from each Age. p_x. Males.	Chance of Living One Year from each Age. p_x. Females.	Of 1,000,000 Males born, the Number Surviving at each Age. l_x.	Of 1,000,000 Females born, the Number Surviving at each Age. l_x.	Of 1,000,000 of both Sexes born (508,770 Males and 491,230 Females). The Number Surviving at each Age. l_x.	Of 1,000,000 of both Sexes born (508,770 Males and 491,230 Females). Population or Years of Life Lived, in and above each Year. Q_x.	Mean after Life-time or Expectation of Life. E_x. Males.	Mean after Life-time or Expectation of Life. E_x. Females.
0	0·82814	0·85934	1,000,000	1,000,000	1,000,000	45,920,642	44·13	47·77
1	·94681	·95051	828,136	859,342	843,464	45,019,089	52·22	54·53
2	·97917	·97986	784,090	816,810	800,163	44,197,275	54·12	56·34
3	·98682	·98666	767,754	800,357	783,769	43,405,309	54·26	56·49
4	·99030	·99045	757,631	789,683	773,376	42,626,737	53·98	56·25
5	·99282	·99294	750,281	782,144	765,932	41,857,083	53·50	55·79
6	·99480	·99478	744,936	776,618	760,499	41,093,867	52·88	55·18
7	·99616	·99608	741,061	772,562	756,535	40,335,350	52·16	54·47
8	·99707	·99696	738,215	769,537	753,602	39,580,282	51·36	53·68
9	·99762	·99748	736,053	767,198	751,353	38,827,804	50·51	52·84
10	·99786	·99769	734,299	765,267	749,511	38,077,372	49·63	51·97
11	·99773	·99758	732,728	763,498	747,843	37,328,695	48·73	51·09
12	·99753	·99740	731,064	761,652	746,091	36,581,728	47·84	50·21
13	·99740	·99730	729,260	759,671	744,199	35,836,583	46·96	49·34
14	·99726	·99720	727,364	757,618	742,226	35,093,370	46·08	48·48
15	·99695	·99694	725,373	755,499	740,172	34,352,172	45·21	47·61
16	·99649	·99653	723,159	753,185	737,909	33,613,131	44·34	46·75
17	·99609	·99620	720,621	750,574	735,335	32,873,509	43·50	45·92
18	·99584	·99604	717,800	747,721	732,498	32,142,592	42·67	45·09
19	·99565	·99598	714,811	744,762	729,523	31,411,582	41·84	44·27
20	·99543	·99586	711,714	741,766	726,427	30,683,582	41·02	43·44
25	·99432	·99498	693,894	725,386	709,363	27,092,709	37·01	39·37
30	·99329	·99382	673,200	705,819	689,223	23,595,047	33·07	35·39
35	·99103	·99218	648,169	682,147	664,860	20,207,596	29·26	31·52
40	·98810	·99005	615,964	653,014	634,164	16,957,225	25·64	27·82
45	·98519	·98830	577,010	619,184	597,727	13,875,672	22·20	24·20
50	·98064	·98505	530,888	580,320	555,170	10,990,312	18·90	20·64
55	·97432	·97977	475,849	533,105	503,975	8,338,589	15·79	17·24
60	·96404	·97072	409,518	473,037	440,720	5,971,126	12·93	14·10
65	·95031	·95813	332,344	398,299	364,743	3,952,986	10·34	11·27
70	·92788	·93757	246,630	309,168	277,251	2,343,547	8·05	8·78
75	·89460	·90689	158,608	210,688	184,191	1,189,793	6·15	6·70
80	·84800	·86374	82,298	118,068	99,870	486,744	4·62	5·05
85	·78642	·80655	31,323	49,925	40,461	148,098	3·45	3·80
90	·70814	·73622	7,724	14,330	10,969	30,369	2·58	2·87
95	·61719	·65806	1,059	2,494	1,764	3,784	1·95	2·23
100	·52092	·58305	138	556	242	573	1·51	1·81

(c) *The expectation of life*, or mean after lifetime, of males and females at the end of each given period.—To find the expectation of life at any age x, the rule is, add together the years of life lived through by the whole of the life-table population after that age, and divide by the number of survivors at that age, or $E_x = \frac{Q_x}{l_x}$. Suppose it is required to find the expectation of life for males at the age of 35, on the basis of this English Life-table. If we refer to that table, and add together the numbers surviving at each age later than 35, we obtain the figure 3,469,353, which is the number of complete five-year periods lived through by the whole of the life-table population

after 35 years of age. These five-year periods equal 17,346,765 years, and as this number of years is lived by 648,169 males, the number of complete years lived by each male is 26·76 years. This result is known as the "curtate expectation of life."

In the above remarks we have confined our attention to the complete quinquennia of life, and have not taken into account that portion of lifetime lived by each person in the quinquennium of his death. In some instances this may be only a few months or days, in others one or more years; but it may be assumed with a fair degree of accuracy, taking one person with another, that the duration of life in the quinquennium of death will be half such a period, that is, 2·5 years. If we add this 2·5 to the curtate expectation of life, the complete expectation of life is obtained. Thus, the complete expectation for males at 35 = 26·76 + 2·5 = 29·26 years. In life-tables where the age-periods are given in single years of life, the addition to be made to the curtate expectation will be 0·5 year. Usually, only the complete expectation of life is given in life-tables.

If reference be made to any life-table, it will be readily seen that the last column is obtained in the same way, and that the mean future lifetime of any person can be obtained by the formula $\frac{Q_x}{l_x}$.

From what has here been explained, it will be gathered that life-tables can be constructed for individual towns as well as districts or countries, provided the necessary facts are available. And owing to the important conclusions which may be drawn from it, a local life-table must henceforth be regarded as indispensable to every Medical Officer of Health. As Tatham has said, it is to him what the two-foot rule is to the mechanic. "In a word, the life-table is the one and only means by which the vague expression 'more or less' of the sanitarian can be reduced to an exact comparative standard." The most recent life-table for the whole of England and Wales is that for the decennium 1891–1900, and already quoted; we have available for comparison the Healthy Districts Life-table for the same period, and also four local life-tables based on the death-rates for 1881–90, namely, those for Manchester (Tatham), Brighton (Newsholme), Glasgow (Chalmers), and London (Shirley Murphy). These four older tables are of the greatest interest as showing the immense difference in the expectation of life in large and crowded manufacturing centres, in the metropolis, and in a typical seaside health resort of magnitude. Reference should be made to all these tables by those desirous of constructing similar local tables for themselves, as details are given for which space is not available in a general work of this kind.

A comparison between the old and new life-tables shows that by the new table for England and Wales the average lifetime of males, or the mean expectation of life at birth, is 44·13 years; this is 4·22 years more than in 1838–54, 2·78 years more than in 1871–80, and 0·47 year more than in 1881–90. As Tatham says, the effect of increased infant mortality during the last decennium is apparent here, for, while at birth the new table shows an addition to the mean after lifetime of barely half a year, at the age of 1 year it shows an addition of 1¼ years, and at the age of 2 years an addition of 13 months. From this age onwards the addition to the mean after lifetime at successive ages falls gradually until at ages 7 to 13 years it is only about two-thirds of a year, after which it rises until it is about three-fourths of a year from ages 14 to 25; it then drops again almost uninterruptedly until about 70, when for a few years the expectation of life by the last two tables is practically identical.

As in the case of males, the expectation of life for females at birth has been raised; the addition being 0·59 year. At the end of the first year of life, the increase amounts to 1·29 years, at the end of the second year to 1·16 years, and at the end of the third to 1·03 years. After this age the excess falls until it is only four-fifths of a year at ages 6 to 8 years, when it rises again and exceeds a year at ages 14 to 20. It then falls gradually until, at ages 55 to 75, the expectation is practically identical by the old and new table.

When we compare the most recent with the earlier Life-tables for Healthy Districts, we find the expectation of life at birth in the newly selected group of healthy districts is 52·87 years for males and 55·71 for females; these expectations show an increase of 1·39 years for males and 1·67 years for females as compared with 1881–90, and an increase of 4·31 years and 6·26 years respectively as compared with 1849–53. The advantage of life-expectation in the healthy districts as compared with the whole of England and Wales in the last decennium was no less than 8·74 years for males and 7·94 for females; while if the comparison be carried back to the period 1838–54 it will be seen that the expectation of life in the healthy districts in the last completed decennium is about one-third greater both for males and for females than it was among the general population in 1838–54. The exceptional risks of the first year of life being passed, the expectation of life in the healthy districts rises by 6·26 years for males and 4·82 years for females to 59·13 and 60·53 respectively. At the age of one year, the expectation shows an advantage of 6·91 years for males and 6·20 years for females in the healthy districts, as compared with the average population. Among both males and females in the healthy districts, the expectation of life increases until the age of 2 years, and then falls gradually, the maximum being reached at the same age as in 1881–90, but one year of age earlier than in 1849–53; in England and Wales, the maximum occurred one year later both in 1881–90 and in 1891–1900, and two years later in 1838–54 and in 1871–80.

The most striking differences in the different life-tables are shown by the figures relating to young children. In all the life-tables the expectation of life increases for a year or two after birth, and then falls continuously until the end of life. The increase is most marked in the first year of life, and is due to excessive mortality in that period. The subsequent fall shows that with low risks of death there is a rapid fall of expectation, amounting in those years where the death-rate is lowest to nine-tenths of a year annually; while at later ages, when the risk of mortality again becomes greater, the reduction of expectation from year to year is small.

The following Table (p. 806), given by Tatham,* is designed to show the age of the maximum expectation of life, the actual and proportional addition to the expectation by the time that maximum is reached, and the year of life in which the expectation returns to its original level. The figures show that with improvement of health conditions, the age of maximum expectation is reached earlier both in England and Wales and in the healthy districts; this being due in part to the very marked fall in the mortality among children between the ages of 1 and 5 years, although it is dependent also upon the decreased death-rates at higher ages. Even in the selected healthy districts the mortality of infants under 1 year of age is very high, although not nearly so high as in the country as a whole. The great excess of mortality occurs principally among children less than 3 months old.

* Tatham: Part I. of the Supplement to Sixty-fifth Annual Report of the Registrar-General, 1907, p. xxxvii.

	England and Wales.				Selected Healthy Districts.		
	1838–54.	1871-80.	1881-90.	1891–1900.	1849–53.	1881 90.	1891–1900.
	Males.						
Expectation of life at birth	39·91	41·35	43·66	44·13	48·56	51·48	52·87
Age of maximum expectation	4	4	3	3	3	2	2
Increase of expectation, from birth to age of maximum — In years	9·90	9·66	9·66	10·13	6·28	6·87	6·96
Increase of expectation, from birth to age of maximum — Per cent.	24·80	23·40	22·10	23·00	12·90	13·30	13·20
Year of life during which the expectation first falls below that at birth	20	18	16	17	14	12	12
	Females.						
Expectation of life at birth	41·85	44·62	47·18	47·77	49·45	54·04	55·71
Age of maximum expectation	4	.4	3	3	3	2	2
Increase of expectation, from birth to age of maximum — In years	8·85	8·58	8·28	8·72	4·96	5·32	5·42
Increase of expectation, from birth to age of maximum — Per cent.	20·50	19·20	17·50	18·30	10·00	9·80	9·70
Year of life during which the expectation first falls below that at birth	18	17	15	15	12	10	10

Taking the recent Healthy Districts Life-table as a standard, a comparison of the life-tables for the last two decennia shows that the number of births of males which would give 1000 survivors at 15 years of age by the new Healthy Districts Table would give only 989 in the corresponding table of 1881–90, and only 893 and 894 respectively in England and Wales in the last and in the preceding decennium. It is noticeable that at the early adult ages the figures relating to England and Wales decrease very slowly, indicating that at these ages the effect of mortality on the number of survivors is almost the same in the country as a whole as it is in the selected districts.

The importance of the figures indicating expectation of life, in life-tables, cannot be overrated, as these expectations of life represent a mean lifetime of all children born, some of whom die immediately after birth, while others survive to extreme old age. It is, therefore, pertinent to inquire how much of this mean lifetime is lived in infancy, how much in the period of school age, in adolescence, in maturity, and in the decline of life. These designations are to some extent arbitrary, but they represent conveniently various periods of life. The column of the life-tables headed P_x shows, for each year or group of years of age, the total years of life lived in that year by those surviving at its beginning, and these values of P_x afford the means of answering the question with some accuracy. Tatham has prepared the Table on p. 807 * which shows, according to the four English and the three Healthy Districts Tables, the number of years of the mean lifetime which were lived in the age-periods indicated by each child born. A marked feature of the table is that the average number of years lived under the age of 5 has remained practically stationary for each sex, while the mean lifetime between the ages 25 and 65 is distinctly increased; this latter fact is of special significance because these years represent the effective

* Tatham: Part I. of the Supplement to Sixty-fifth Annual Report of Registrar-General, 1907, p. xxxix.

working period of life. The average lifetime of males rose at these ages between the periods 1838–54 and 1891–1900 from 19·35 years to 22·24 years, and of females from 20·13 to 24·07 years; the proportion from the whole period of 40 years having risen from 48 to 56 per cent. for males and from 50 to 60 per cent. for females. In the healthy districts the proportion in 1849–53 was 60 per cent. for each sex; in 1891–1900 it reached 67 per cent. for males and 70 per cent. for females. Both in England and Wales and in the healthy districts, the proportion of lifetime lived in infancy has declined steadily among both males and females; the same feature is observable also at school age, and to a less degree at ages 15 to 25 years.

Life-period.	Age Limits of Period.	England and Wales.				Selected Healthy Districts.		
		1838-54.	1871-80.	1881-90.	1891-1900.	1849-53	1881-90.	1891-1900.
		Males.						
Infancy . .	0–5	3·94	4·01	4·02	3·99	4·29	4·30	4·31
School age .	5–15	6·92	7·11	7·35	7·35	7·88	8·13	8·21
Adolescence .	15–25	6·51	6·79	7·12	7·11	7·50	7·89	7·99
Maturity	25–35	5·95	6·29	6·69	6·72	6·95	7·49	7·63
	35–45	5·31	5·62	6·04	6·15	6·37	6·95	7·17
	45–55	4·54	4·76	5·16	5·29	5·72	6·25	6·52
	55–65	3·55	3·63	3·96	4·08	4·82	5·22	5·49
Decline . .	65 and upwards	3·19	3·14	3·32	3·44	5·03	5·25	5·55
Total . .	All ages.	39·91	41·35	43·66	44·13	48·56	51·48	52·87
		Females.						
Infancy . .	0–5	4.07	4·14	4·17	4·14	4·39	4·43	4·44
School age .	5–15	7·19	7·40	7·68	7·66	8·07	8·41	8·48
Adolescence .	15–25	6·73	7·07	7·44	7·41	7·61	8·12	8·23
Maturity	25–35	6·12	6·58	6·99	7·05	7·00	7·69	7·87
	35–45	5·46	5·95	6·38	6·52	6·37	7·15	7·43
	45–55	4·73	5·20	5·63	5·79	5·71	6·53	6·86
	55–65	3·82	4·21	4·55	4·71	4·89	5·60	5·92
Decline . .	65 and upwards	3·73	4·07	4·34	4·49	5·41	6·11	6·48
Total . .	All ages	41·85	44·62	47·18	47·77	49·45	54·04	55·71

Life-capital.—If we apply the figures of a life-table to the existing or estimated population of a community in groups of ages at a given period, we obtain the aggregate future lifetime of each of these populations, or, as it has been appropriately called, the life-capital of the community in that particular period or year. Taking England and Wales as an example, for which we have available a life-table based upon the most recent facts as gained at the last census, we have been able to construct the Table on page 808.

This Table shows that so long as the age constitution remains as at the last census enumeration, and the death-rates at the various ages continue as in the decennium 1891–1900, the average life-capital of the population of England and Wales, taking young and old together, is 38·7 years; and that under the same conditions the ordinary expenditure of this capital per annum is 2·5 per cent.

The method here indicated in a simple form is capable of considerable extension and application, particularly if life-tables for given cities, towns, or large areas be prepared. Considerations of space render it impossible to follow out here all the possible and practical uses to which life-tables readily lend themselves. It is sufficient to have indicated some of the most important and striking of these uses, and to have shown that, in a properly prepared life-table for its district, the Sanitary Authority possesses a powerful instrument for statistical investigation. By its aid we can learn how much of the best and most useful part of human life is wasted owing to the life conditions of the community, and we can also use it as a measure of future sanitary progress or retrogress.

	Expectation of Life.		Population.		Life-capital.	
	Males.	Females.	Males.	Females.	Males.	Females.
0 years	44·13	47·77	1,876,242	1,939,786	82,798,560	92,663,577
5 ,,	53·50	55·79	1,758,461	1,805,605	94,077,663	100,734,702
10 ,,	49·63	51·97	1,680,528	1,802,820	83,404,702	93,692,555
15 ,,	45·21	47·61	1,670,704	1,662,634	75,532,527	79,158,004
20 ,,	41·02	43·44	1,581,657	1,630,065	64,879,570	70,810,023
25 ,,	37·01	39·37	2,523,644	2,673,250	93,400,064	105,245,852
35 ,,	29·26	31·52	1,855,553	1,986,408	54,293,480	62,611,780
45 ,,	22·20	24·20	1,318,865	1,489,658	29,278,803	36,049,723
55 ,,	15·75	17·24	847,884	1,000,626	13,354,173	17,250,792
65 ,,	10·34	11·27	471,058	606,064	4,880,739	6,830,341
75 and upwards	4·11	4·82	188,466	251,285	774,595	1,211,193
All ages .	—	—	15,773,062	16,848,201	596,674,876	666,258,542
Total . .	—	—	32,621,263		1,262,933,418	

Tests of Longevity.—These resolve themselves practically into attempts to measure the duration of life. The *expectation of life* or mean after lifetime has been explained already as one of the deductions to be made from the study of a life-table; it is identical with the "mean duration of life at birth," but the *mean duration of life* for any later age signifies the age in question plus the mean after lifetime at that age. In the absence of life-tables, the late Dr. Farr showed that the mean duration of life, or mean after lifetime, could be approximately calculated from the birth- and death-rates by the following formula, in which B = birth-rate and D = death-rate, while x = the expectation of life at birth.

$$x = \frac{2}{3} \times \frac{1000}{D} + \frac{1}{3} \times \frac{1000}{B}.$$

Say a town has a birth-rate of 32 and a death-rate of 28 per 1000, then, applying this formula, we get $\frac{2000}{3D} + \frac{1000}{3B}$ or $\frac{2000}{84} + \frac{1000}{96} = 34$, as the mean expectation of life at birth under those conditions.

Willich gives another formula, in which x = the expectation of life at any age a, between 25 and 75 years, then :—$x = \frac{2}{3}(80 - a)$, and applying this, say for calculating the expectation of life at 53 years of age, we get $\frac{2}{3}(80-53) = x$ or 18 years.

The *mean age at death* of a population is the sum of the ages at death divided by the number of deaths. It is no good test of the relative healthiness of populations unless due corrections be made for age and sex distribution. As Farr says, a population of ensigns might show a mean age at death of 22, and a population of generals over 48, but the latter population would not be more healthy than the former; it would merely consist of persons of a different age. A high birth-rate may reduce the age, though the health of the community may be extremely good. If the birth-rate be high, there will be in consequence a greater proportion of infants or young children in the population. These, we know, have a relatively high death-rate, with the result that the average age of death will be proportionately reduced. In this country the mean age at death averages 45 for males and 48 for females. Farr has shown that it is nearly equivalent to the reciprocal of the death-rate *minus* one-third of the difference between the reciprocal of the death-rate and that of the birth-rate; or two-thirds the reciprocal of the death-rate *plus* one-third that of the birth-rate. Suppose the death-rate to be 1 in 46, and the birth-rate 1 in 29, we have $\frac{46 \times 2}{3} + \frac{29}{3} = 40{\cdot}3$ as the mean age at death.

The *probable duration of life* is practically the age at which exactly half of any given number of children born alive will have died; or, in other words, there are equal chances of their dying before and after that age. It is sometimes spoken of as the equation of life, or *vie probable* of French writers. All these terms are more or less unfortunate, as there is a probability for every possible duration of life. Regarded strictly as defined above, the probable duration of life is of no great value as a test of longevity; it can only be obtained from what is called a life-table, and as so determined for England and Wales gives the probable duration of life for each male 44 years, and for each female 47 years. The probable duration of life is often confounded with another statistical expression, called the *mean duration of life*, which is the *vie moyenne* of French writers. If we imagine an absolutely stationary population, that is, one in which age and sex distribution does not change, then, starting from birth, the mean duration of life would be identical with the mean age at death, and with the expectation of life at birth as determined by means of life-tables. But such a stationary population is rare, and in an ordinary community, whose numbers are constantly being disturbed by migration or other causes, the mean duration of life really signifies the present age in years *plus* the probable duration of life after having attained a given age, and which is more commonly called the mean after lifetime, or expectation of life. For comparative purposes, it is often more convenient to employ the term mean duration of life as indicating the expectation of life at birth; but if it is required to remove the disturbing influence of infant mortality, then the mean after lifetime, or expectation of life at a later age, must be taken. This expression, expectation of life, must not be taken to imply that any individual may reasonably *expect* to live a given number of years, because it has no true relation to the most probable duration of the lifetime of any given person. It merely shows the *average* number of years which a person, at a given age, lives, and in that sense constitutes the true measure of the chances of living which a mixed community has. Its estimation is made by means of a life-table, constructed from census figures on the basis of the number living and the number dying at each age. Such a table shows how many out of, say, 1,000,000 persons supposed to be born at the same time will survive at the end of each year or term of years. The same table will also show the sum of the number of years which they live, and if this sum of

these years be divided by the number living at any given age, the result will be the expectation of life for that given age.

The *mean age of the living*, obtained by dividing the sum of the ages of the population at the census by the number of the population, has been proposed as a test of longevity. At best it is unreliable and, as Newsholme says, in insanitary areas the mortality may spend itself chiefly among young children; apart from this, immigration is a circumstance which especially disturbs the mean age of the living and renders it most untrustworthy as an index of longevity.

Value of Statistical Facts and Methods.—We have now discussed the chief kinds of statistical material generally at the disposal of the sanitarian, but before closing the subject it is necessary to indicate the chief sources of fallacy in statistics and the lines along which recent statistical methods have advanced. For much of this work we are indebted to Karl Pearson and others who have brought statistics into a branch of exact science. As it is probable that these methods must sooner or later be applied to many problems connected with the sanitary welfare of the people, it is desirable that the student should have some idea of modern statistical notation and of the meaning of the various terms used. Unfortunately, the subject is full of technicalities and limitations of space prevent our presenting more than an elementary summary, but those desirous of pursuing the subject further should consult the special memoirs and reviews which give full details of the mathematics involved.*

In an ideal mass of statistics the facts must (1) be all correctly observed; (2) they must be of the same kind and order; (3) they must be all localised both in regard to time and place; (4) they must be sufficiently numerous to give correct averages, and extend over sufficient length of time. It will be at once obvious that these various essentials are not easy to obtain. It has already been explained that while it is easy enough to ascertain correctly the numbers of a people during the census year, it is less simple to do so during intermediate years. Similarly, differences of degree or intensity, causation, or virulence of diseases render their comparison, by reducing their statistics to the same order and kind, extremely difficult. So, too, the importance of localising statistics, both in respect of time and place, is made clear by pointing out the absurdity of attempting to construct a particular disease-rate for some health resort from the deaths of persons occurring there from that special affection. The fourth essential for an ideal statistical series is well expressed in a mathematical statement that the error diminishes as the square root of the increased number of observations; in other words, the smaller the total number of facts the larger will be the relative percentage of error displayed by them, and the larger the number of facts collected the smaller will be the margin of error.

Given a number of facts, each of which can be expressed by a numerical value, an *average* or *mean number* is obtained by adding all the numerical values and dividing by the number of facts. The mean or average is really a number which lies between the highest and lowest of a series of numbers, and has a definite dependence upon the whole of the series. The terms mean and average are often used synonymously; regarded mathematically, there are several kinds of means. Thus the simple average or *arithmetic* mean of four numbers, such as a, b, c, d, is conveniently written as

* In this connection, the student should consult the following:—Pearson's *Grammar of Science*, London, 1900; Davenport's *Statistical Methods*, New York and London, 1904; Elderton's *Frequency Curves and Correlation*, London, 1906; *also* various papers in *Biometrika*, vols. i.–v.; *also* various issues of the Biometric series of the *Drapers' Company Research Memoirs*, London, 1906 and 1907.

$\frac{a+b+c+d}{4}$, but their *geometric* mean would be $\sqrt[4]{a\ b\ c\ d}$, while their *harmonic* mean stands thus: $\frac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$, and their *quadratic* mean is $\sqrt{\frac{a^2+b^2+c^2+d^2}{4}}$.

Of course if the terms of the series of numbers are unequal, then the quadratic mean will be the highest, next the arithmetic, and then the geometric and harmonic means; but if all the terms of the series are equal, then their means are equal too. The chief practical question in vital statistics is not so much the value of a true average, or arithmetic mean, or even the probable value of a fixed quantity, but rather the value of a variable quantity. If we consider any measurable character in a group of people, we find that there is variation, and the first essential is some means of describing this variability. For this purpose, biometricians use the *standard deviation*, a function usually expressed by the symbol σ.

Mathematically, standard deviation can be defined by the following expression, $\sigma = \sqrt{\frac{n_1 a_1^2 + n_2 a_2^2 + n_3 a_3^2 + n_4 a_4^2}{\mathrm{N}}}$ . . . ; in which n_1, n_2, &c., are the numbers of individuals having the same measurements, and a_1, a_2, &c., are the number of units separating each group value from the mean value of the whole sample N. Suppose in a sample of 100 poppy capsules 15 individuals had 5 stigmatic bands, 30 had 6, 30 had 7, 20 had 4, and 5 had 3, then the arithmetic mean of the whole would be 5·6 stigmatic bands, and the standard deviation would be $\sigma = \sqrt{\frac{15\,(0{\cdot}6)^2 + 30\ \,(0{\cdot}4)^2 + 30\,(1{\cdot}4)^2 + 20\,(1{\cdot}6)^2 + 5\,(2{\cdot}6)^2}{100}}$ or $\sqrt{1{\cdot}54} = 1{\cdot}24$.

The standard deviation is a concrete number which measures the way the frequencies are distributed in terms of the unit of measurement. Since the greater the distance between any group value and the mean, the larger is the number by which the total of individuals in the group is multiplied, the standard deviation affords us a knowledge as to how the observations are distributed about the mean; the more they are scattered the larger will be the standard deviation. In the form of integrals, the standard deviation is written $\sigma = \sqrt{\left\{\frac{\int f_x \times x^2 dx}{\int f\, dx}\right\}}$ where the distances x are measured from the mean and f_x is the frequency corresponding to x.

In considering the respective degrees of variation in two samples, we cannot compare the standard deviations themselves unless the means coincide; when this is not the case, we reduce to a common form by dividing each standard deviation by its corresponding mean and multiplying by 100; this is termed the *co-efficient of variation.* Thus, say the standard deviation of 413 vegetable marrows was 1·946 ounce, and the mean of the sample was 11·24 ounces; also that of a similar number of pumpkins the standard deviation was 2·016 ounces, with a mean of 12·01 ounces. In these cases, the co-efficient of variation will be 17·3 and 16·8 respectively, and the variabilities are, accordingly, in the ratio of as 17·3 is to 16·8.

The diagram given in Fig. 161 shows two curves having the same mean A and of approximately the same area, but the dotted curve has the larger standard deviation because it spreads out more on each side of the mean. If the reader understands the algebraic expressions given above, he will notice that the standard deviation is not dependent on the number of

individuals or cases, that is, on the absolute size of the curve, but merely on the way they are distributed; it measures the spread of the statistics from the mean.

If statistics are arranged so as to show the number of times or frequency with which an event happens in a particular way, then the arrangement is a frequency distribution. To describe such distributions it is necessary to have a formula, and the term *frequency curve* has been adopted for the purpose. When statistics give the number of cases for an exact value of the independent variable, the simplest procedure is to plot them in a diagram by drawing at equal intervals (x) along a horizontal line a series of (vertical) ordinates whose heights must be proportional to the frequency of the variates or individuals; then join their tops; but when the statistics give the number of cases falling in certain groups of values there is a complication, to meet which we can either draw a rectangle standing on the entire base, or put in ordinates at the middle points of the bases and then join their tops. The former method gives a better idea of the amount of information conveyed by the statistics, but realising the possible shape of the curve, the latter is the more convenient. All statistics tend toward a smooth series as the total number of individuals or cases is increased, and from this we can realise how practical statistics lead naturally to the conception of a frequency curve in order to describe the smooth distribution that would be obtained if an infinite supply of homogeneous material were available for investigation. Thus, if we mix a large number of beans of two distinct colours and take out a fixed quantity of the mixture and record the number of beans of either colour in each drawing, we should obtain a continuous curve from a large number of drawings, in other words, a frequency curve will give a frequency corresponding to every value of the independent variable along the whole range of the distribution, and does not restrict us to a conception of a few more or less arbitrary groups as is necessarily done by the actual statistics.

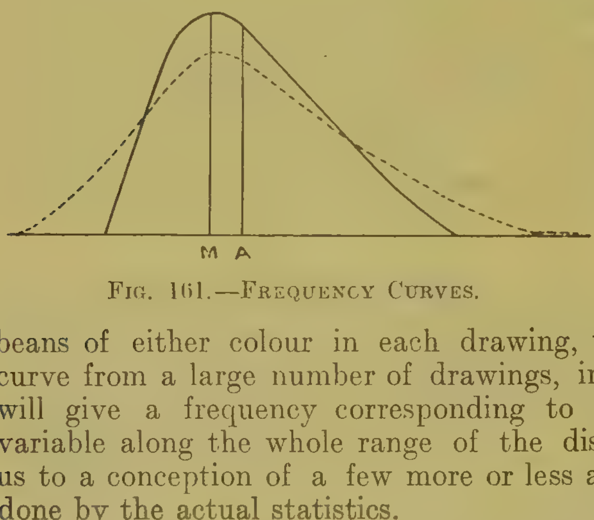


FIG. 161.—FREQUENCY CURVES.

Assuming that certain data have been gathered and arranged, it is necessary to determine the law of distribution of the variates. To get at this law we must determine certain constants, the more important of these are:—(*a*) the standard deviation, (*b*) the mean, and (*c*) the mode. The standard deviation has been explained; it is expressed usually by the symbol σ. The *average* or *mean*, commonly written as A, is the centre of gravity of the frequency polygon; it is found by the formula $A = \frac{\Sigma (\nu . f)}{n}$, in which ν is the magnitude of any variate; f is its frequency; Σ is the sum of the products of all variates into frequency; while n is the number of variates. Thus, if in a series of 25 variates the number of 3·2 occurs once, 3·7 once, 4·2 three times, 4·7 three times, 5·2 seven times, 5·7 five times, 6·2 three times, 6·7 once, and 7·2 once, then the average or mean is 5·24. The *mode*, commonly written M, is the characteristic that occurs most frequently, or, in other words, is the position of the maximum ordinate, and its calculation can only be made approximately, unless we know the law connecting the variates. From the rough statistics we cannot tell which is the greatest ordinate; this can be done only when we know the frequency curve. A

mode determined by inspection of the seriated data would be the approximate or empirical mode; in the above example it is 5·2. On construction of a theoretical curve, then the mode agreeing most closely with the observed distribution would be the theoretical mode.

An examination of frequency distributions or statistical series shows that most of them start at zero, gradually rising to a maximum and then falling often at a different rate. If the rise and fall are at the same rate, distribution will be symmetrical about its mean, and this mean will coincide obviously with the mode. This is a normal curve as shown in Fig. 162. If, however, the mean and mode do not coincide, the curve will be more or less asymmetrical or "skew," and the difference between the mean and mode is therefore a function of the *skewness* or deviation from symmetry. If the mean is on the left-hand side of the mode when the statistics are plotted

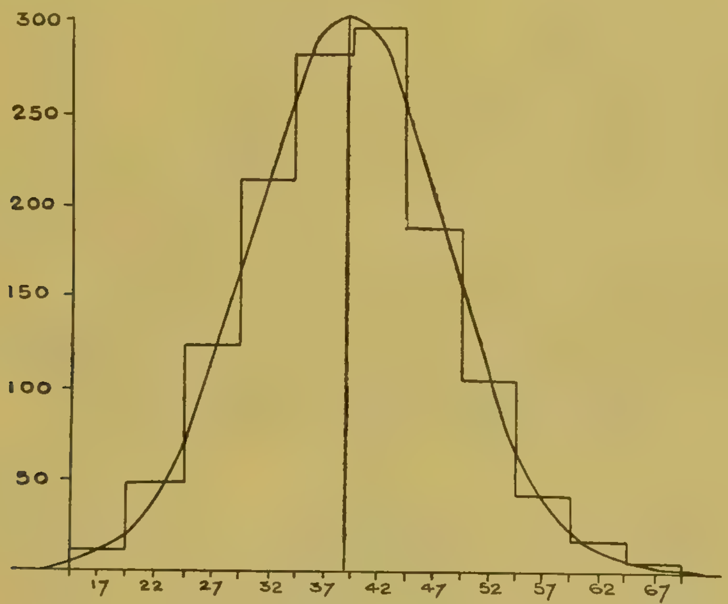


Fig. 162.—Frequency Curve. Pearson's Type VII.

out in diagram this function will be negative. The degree of skewness is measured by dividing the distance between mean and mode by the standard deviation. A reference to Fig. 161 will make this clear; it gives two curves having the same mean A and the same mode M, but with different standard deviations; the dotted curve with its larger standard deviation is more symmetrical than the other curve. Summarising these functions, we may say that the mean and mode fix the position of the curve on its axis; the standard deviation shows how the material is distributed about the mean, and the skewness shows the amount of the deviation from symmetry exhibited by the material. If the mean is greater than the mode, skewness is positive; if the mean is less than the mode, skewness is negative.

In practice most frequency distributions or series of values requiring graduation can be adequately described by using one of seven curves. Their graphical characters may be summarised in this way:—(1) the normal curve, symmetrical and unlimited in either direction (Fig. 162); (2) the skew curve, of limited range in both directions (Fig. 163); (3) the symmetrical curve, limited in both directions (Fig. 164); (4) the skew curve, whose range is limited in one direction (Fig. 165); (5) a skew curve of unlimited range (Fig. 166); (6) a skew curve of limited range in one direction (Fig. 167); (7) a skew curve, of limited range in one direction (Fig. 168).

The calculation of a frequency curve to correspond with observed statistical data is a matter of some difficulty, involving a certain amount of mathematical knowledge. A complete explanation of the whole of the

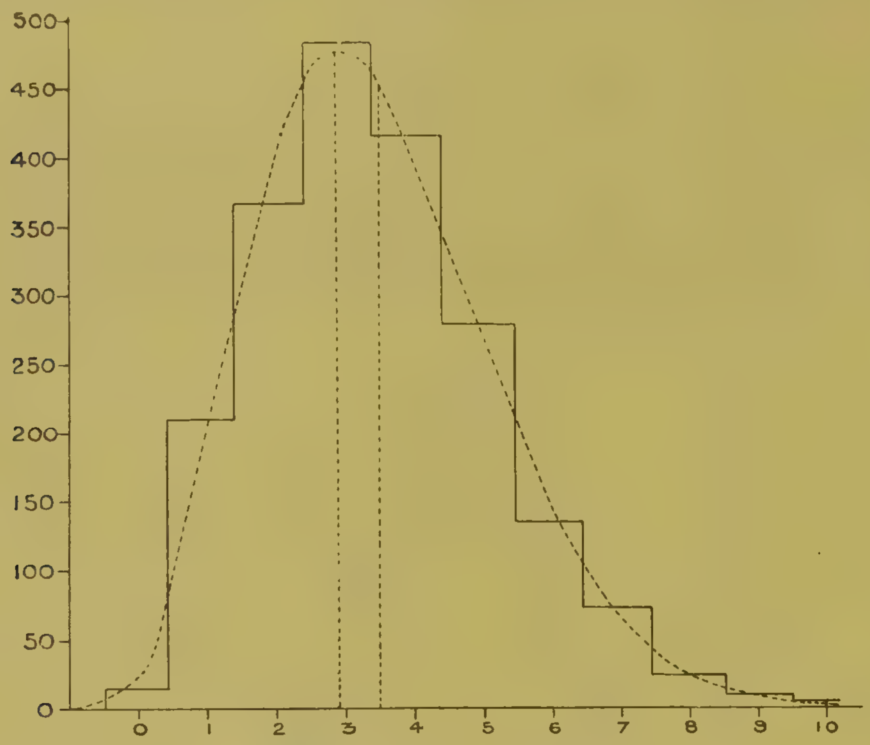


FIG. 163.—FREQUENCY CURVE. PEARSON'S TYPE I.

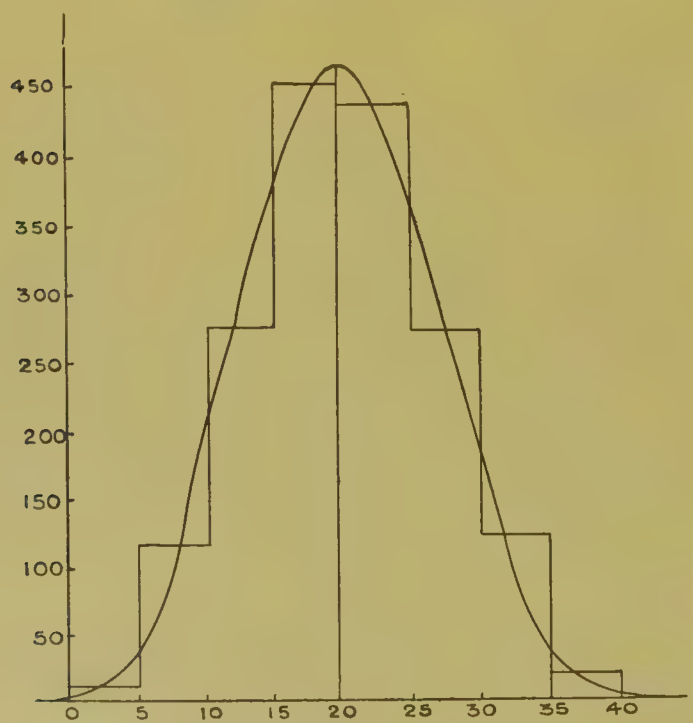


FIG. 164.—FREQUENCY CURVE. PEARSON'S TYPE II.

steps cannot be given here, but the following summary may serve to explain the principles; for precise details and their mathematical proof, the student should consult special treatises.*

* *See* Karl Pearson, *also* Davenport and Elderton, *op. cit.*

Arrange the statistics or variables in sequence with their corresponding frequencies. Next determine the mean of the variables or magnitudes. Take a variable near the mean and call it ν_0, regarding it as a zero point;

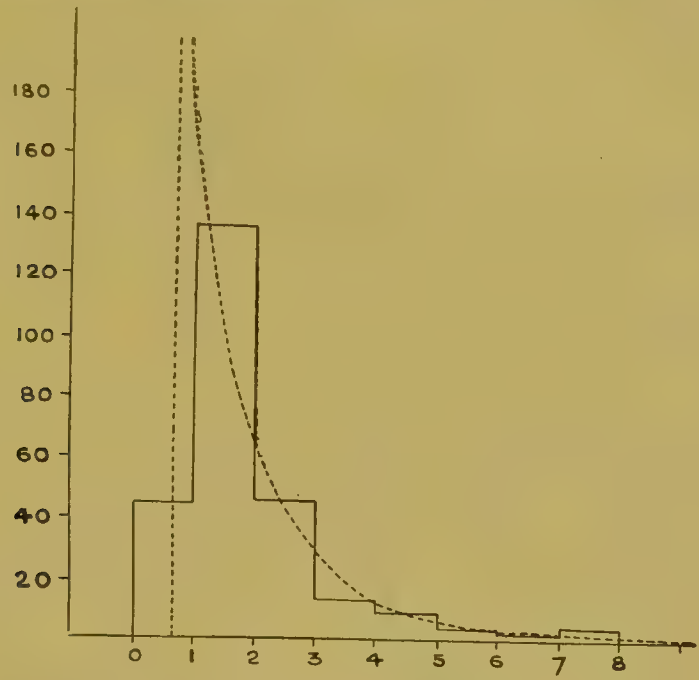


FIG. 165.—FREQUENCY CURVE. PEARSON'S TYPE III.

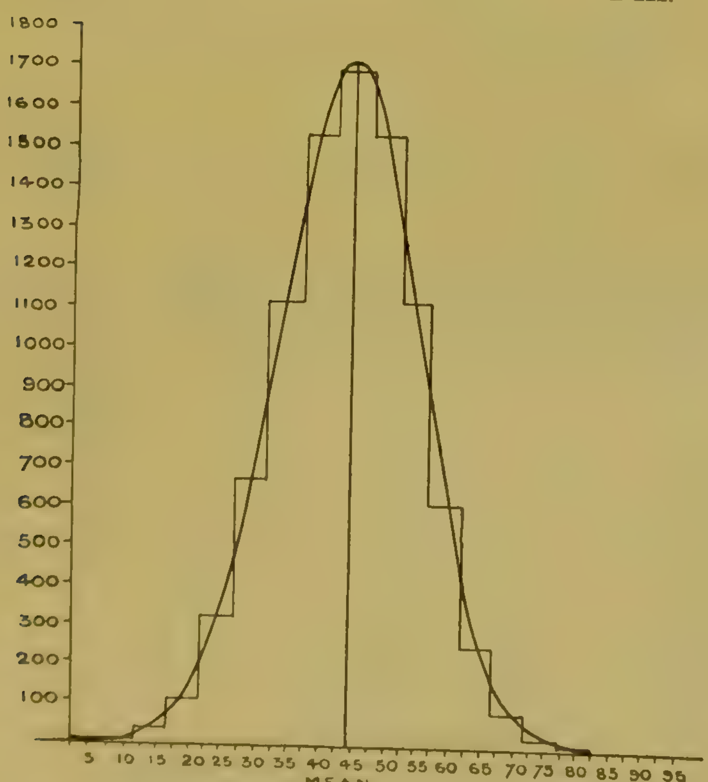


FIG. 166.—FREQUENCY CURVE. PEARSON'S TYPE IV.

then the departure of all the other variables from this variable will be -1, -2, -3, &c., and $+1$, $+2$, $+3$, &c., or $\nu \pm \nu_0$.

The next step is to calculate the moments of the curve about this convenient vertical. This is done in the following manner. Add the products

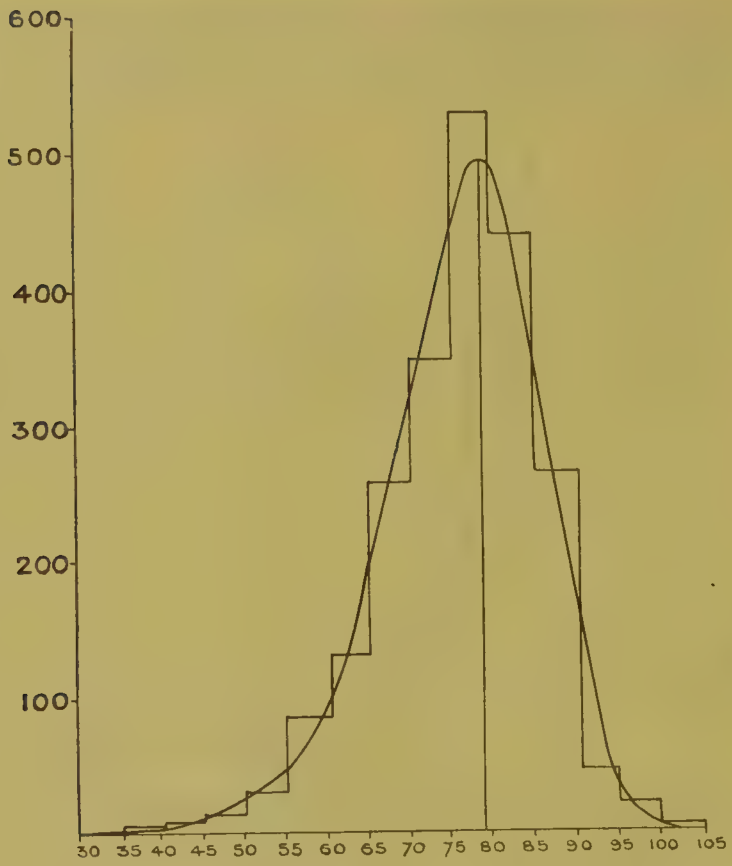


FIG. 167.—FREQUENCY CURVE. PEARSON'S TYPE V.

of all the departures from the selected variable multiplied by their respective frequencies (f) and divide by the total number of variables (n). Call the quotient ν_1 or $\nu_1 = \dfrac{\Sigma f(\nu - \nu_0)}{n}$.

Add the products of the squares of all the departures multiplied by the frequency of the corresponding variable and divide by n; call the quotient ν_2 or $\nu_2 = \dfrac{\Sigma f(\nu - \nu_0)^2}{n}$.

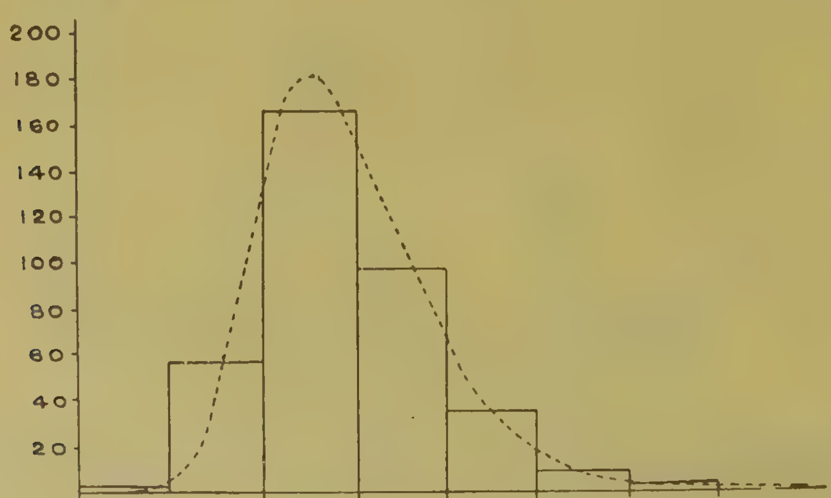


FIG. 168.—FREQUENCY CURVE. PEARSON'S TYPE VI.

Add the products of the cubes of all the departures multiplied by the frequency of the corresponding variable and divide by n; call the quotient ν_3 or $\nu_3 = \dfrac{\Sigma f(\nu - \nu_0)^3}{n}$.

Add the products of the fourth powers of all the departures multiplied by the frequency of the corresponding variable and divide by n; call the quotient ν_4 or $\nu_4 = \dfrac{\Sigma f(\nu - \nu_0)^4}{n}$.

These values, $\nu_1, \nu_2, \nu_3, \nu_4$, are the respective moments of the curve about ν_0.

The next step is to transfer the moments to the centroid vertical or vertical through the mean. These are written $\mu_1, \mu_2, \mu_3, \mu_4$, and their calculation differs according as to whether the series is one of integral variables or of graduated variables. In the case of integral variates, $\mu_1 = 0$; $\mu_2 = \nu_2 - \nu_1^2$; $\mu_3 = \nu - 3\nu_1\nu_2 + 2\nu_1^3$; $\mu_4 = \nu_4 - 4\nu_1\nu_3 + 6\nu_1^2\nu_2 - 3\nu_1^4$; $\mu_5 = \nu_5 - 5\nu_1\nu_4 + 10\nu_1^2\nu_3 - 10\nu_1^3\nu_2 + 4\nu_1^5$.

In the case of graduated variates, $\mu_1 = 0$; $\mu_2 = [\nu_2 - \nu_1^2 - \frac{1}{12}]\lambda^2$; $\mu_3 = [\nu_3 - 3\nu_1\nu_2 + 2\nu_1^3]\ \lambda^3$; $\mu_4 = [\nu_4 - 4\nu_1\nu_3 + 6\nu_1^2\nu_2 - 3\nu_1^4 - \frac{1}{2}(\nu_2 - \nu_1^2) + \frac{7}{240}]\lambda^4$; in which λ is the class range expressed in the same unit as the average. The average will clearly be the magnitude or variable which has been selected as $\nu_0 + \nu_1$.

We next proceed to find the value of β_1 and β_2 or the ratios of the moments. Since $\beta_1 = \dfrac{\mu_3^2}{\mu_2^3}$, and $\beta^2 = \dfrac{\mu_4}{\mu_2^2}$, it is easy to obtain these from the preceding results.

From the values of β_1 and β_2, we next determine the criterion or k, sometimes called the "critical function." The classification of any empirical frequency polygon depends upon the value of its critical function. Karl Pearson gives the following formula for the calculation of this function, namely:—

$k = \dfrac{\beta_1(\beta_2 + 3)^2}{4(4\beta_2 - 3\beta_1)(2\beta_2 - 3\beta_1 - 6)}$. When k is 0 and β_1 is 0, while β_2 is equal to 3, then the probable curve will be the normal curve or that shown in Fig. 162; when k is less than 0, the type of curve will be probably as Fig. 163; when k and β_1 are 0 and β_2 less than 3, then the curve will be as Fig. 164; when k is infinite, then the curve will conform to the type drawn in Fig. 165; when k is greater than 0 but less than 1, then the curve will be as Fig. 166; if k be 1 then the curve type will follow Fig. 167; when k is greater than unity, but less than infinity, then Fig. 168 represents the type of the theoretical curve.

The following values must now be calculated, namely, the ratio or r, the skewness or a; the mode or M; the range or l; and the moment of each variable about the middle of each range, usually written m_1, m_2, and so on. The value of $r = \dfrac{6(\beta_2 - \beta_1 - 1)}{6 + 3\beta_1 - 2\beta_2}$. The skewness or $a = \frac{1}{2}\sqrt{\beta_1}\dfrac{r+2}{r-2}$. The mode or M = the mean or $A - \frac{1}{2}\dfrac{\mu_3}{\mu_2}\left\{\dfrac{r+2}{r-2}\right\}$. The range, variously written as l or b, is found by the formula $l = \dfrac{a}{2}\sqrt{\{\beta_1(r+2)^2 + 16(r+1)\}}$, this represents the total range of the curve along the abscissa line, while l_1 and l_2 are the ranges to the one side or the other of the ordinate at the origin of the curve, commonly written y_0. The value of $l_1 = \frac{1}{2}(l - Dr)$ where D is the distance between the mean and the mode; $l_2 = l - l_1$. The value of $m_1 = \dfrac{l_1}{l}(r-2)$, while that of $m_2 = r - 2 - m_1$.

Having determined these data we are now in a position to calculate y_0 or the ordinate at the origin of the curve by the following formula :—
$y_0 = \frac{N}{l} \cdot \frac{}{(m_1+m_2)^{m_1+m_2}} \cdot \frac{\Gamma(m_1+m_2+2)}{\Gamma(m_1+1)\Gamma(m_2+1)}$, where N is the sum of the frequencies and Γ is a function to be obtained from mathematical tables (*see* Appendix). To solve this equation it will be necessary to determine the value of each parenthetical quantity following the Γ sign and find the corresponding value of Γ from a table of functions. It is, however, sometimes easier to calculate the value of y_0 from the following approximate formula :—

$$y_0 = \frac{N}{l} \cdot \frac{(m_1+m_2+1)\sqrt{m_1+m_2}}{\sqrt{2\pi m_1 m_2}} e^{\frac{1}{12}\left(\frac{1}{m_1+m_2} - \frac{1}{m_1-m_2}\right)}$$

in which e is the base of the Napierian system of logarithms or 2·71828 and π is 2·14159.

With these data the theoretical curve of Type I. (Fig. 163) may be drawn. It will be obvious that the calculations will be facilitated by the use of logarithms. The formula for the curve, where y is a varying ordinate value and x is the abscissa, is as follows :—$y = y_0\left(1+\frac{x}{l_1}\right)^{m_1}\left(1-\frac{x}{l_2}\right)^{m_2}$

As an example of calculating the theoretical curve corresponding with observed data we may take the following case. Assume we have a series of figures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 occurring with the respective frequencies of 15, 209, 365, 482, 414, 277, 134, 72, 22, 8, and 2. If we assume the ordinate ν_0 to pass through the fourth variable we get, or are able to make, the following table on the basis of the preceding formulæ :—

ν	$\nu - \nu_0$.	f	$f(\nu-\nu_0)$.	$f(\nu-\nu_0)^2$.	$f(\nu-\nu_0)^3$.	$f(\nu-\nu_0)^4$.
0	−4	15	−60	240	−960	3,840
1	−3	209	−627	1881	−5643	16,929
2	−2	365	−730	1460	−2920	5,840
3	−1	482	−482	482	−482	482
4	0	414	0	0	0	0
5	1	277	277	277	277	277
6	2	134	268	536	1072	2,144
7	3	72	216	648	1944	5,832
8	4	22	88	352	1408	5,632
9	5	8	40	200	1000	5,000
10	6	2	12	72	432	2,592
		$\Sigma = 2000$	−998	6148	−3872	48,568

Further calculation on the lines which have been explained show that $\nu_1 = -0·499$, $\nu_2 = 3·074$, $\nu_3 = -1·936$, $\nu_4 = 24·284$; A = 3·501; $\mu_1 = 0$, $\mu_2 = 2·8249$, $\mu_3 = 2·4172$, $\mu_4 = 24·8262$; $\beta_1 = 0·2591$, $\beta_2 = 3·1108$; $k = -0·373$, therefore the curve is of Pearson's Type I.; $r = 19·985$; $a = 0·31115$; D = 0·523; $l = 18·0448$, $l_1 = 3·7965$, $l_2 = 14·248$; $m_1 = 3·784$, $m_2 = 14·2$; $y_0 = 475·24$ or the frequency of the modal class, while the position of the mode y_0 on the abscissa line will be A − D or 3·501 − 0·523 = 2·978. Hence, we could plot a curve as shown in Fig. 163 in which the frequencies or heights of the' theoretical ordinates will be 21·1, 185·8, 395·1, 475·2, 405·6, 272·1, 147·6, 65·9, 24·1, 7, and 1·6, as compared with the observed frequencies given in the example and plotted in the figure.

To Karl Pearson we are indebted for formulæ to calculate the theoretical

curves of the other types. Thus the normal curve (Fig. 162) is represented by $y = y_0 e^{-x^2/c}$, in which $c = 2\mu_2$ and $y_0 = \dfrac{N}{\sqrt{2\pi\mu_2}}$. This formula, like the one explained, gives the value of any ordinate y or any class at any distance x from the mode. The other symbols are as already explained.

The curve known as Type II. is determined by the formulæ $m = \dfrac{5\beta_2 - 9}{2(3-\beta_2)}$; $l = \dfrac{2\mu_2\beta_2}{3-\beta_2}$; while $y_0 = \dfrac{N \times \Gamma(2m+2)}{l2^{2m+1}\{\Gamma(m+1)\}^2}$, and $y = y_0\left(1 - \dfrac{x^2}{l^2}\right)^m$.

The formulæ for the Type III. curve are the mode = mean $- \dfrac{1\mu_3}{2\mu_2}$ while skewness or $a = \frac{1}{2}\dfrac{\mu_3}{\mu_2{}^{3/2}}$; $l = \dfrac{2\mu_2{}^2}{\mu_3} - \dfrac{\mu_3}{2\mu_2}$; $\gamma = \dfrac{2\mu_2}{\mu_3}$; and $y_0 = \dfrac{N}{l}\,\dfrac{p^{p+1}}{e^p\Gamma(p+1)}$ where $p = \gamma l$ the formula for the curve is $y = y_0 e^{-\gamma x}\left(1 + \dfrac{x}{l}\right)^{\gamma l}$.

The curve Type IV. is the commonest of biological skew curves, in its calculations we have the following formulæ :—$r = \dfrac{6(\beta_2 - \beta_1 - 1)}{2\beta_2 - 3\beta_1 - 6}$; $m = \frac{1}{2}(r+2)$; $a = \frac{1}{2}\sqrt{\beta_1\dfrac{r-2}{r+2}}$; $l = \sqrt{\dfrac{\mu_2}{16}}\,\sqrt{\{16(r-1) - \beta_1(r-2)^2\}}$;

$$y_0 = \frac{N}{l}\sqrt{\frac{r}{2\pi}}\;\frac{e^{\frac{\cos^2\phi}{3r} - \frac{1}{12r} - \phi\nu}}{(\cos\phi)^{r+1}},$$

in this ϕ is an angle whose tangent is $\dfrac{\nu}{r}$. It must be remembered that in this curve the origin is not at the mode, but is $+\dfrac{\nu l}{r}$ from the mean. The formula for the final curve is $y = y_0\left(1 + \dfrac{x^2}{l^2}\right)^{-m} e^{-\nu \tan^{-1}\frac{x}{l}}$.

To compare any frequency polygon of Type V. with its theoretical curve, we have $y = y_0 x^{-p} e^{-\gamma/x}$; in this $p = 4 + \dfrac{8 + 4\sqrt{\{4-\beta_1\}}}{\beta_1}$ and $\gamma = (p-2\sqrt{\mu_2(p-3)})$. Similarly $y_0 = \dfrac{N\gamma^{p-1}}{\Gamma(p-1)}$. The skewness or $a = \dfrac{2\sqrt{p-3}}{p}$. The origin of the curve is mean $- \dfrac{\gamma}{p-2}$, and the mode = mean $- \dfrac{2\gamma}{p(p-2)}$.

For curves of Type VI., $y = y_0(x-l)^{q_2}x^{-q_1}$. The range is from a to ∞, and the method is like that of Type I., the functions $1 - q_1$ and $1 + q_2$ being roots of the equation just as $1 + m_1$ and $1 + m_2$ were in Type I. When μ_3 is negative $1 - q_1$ is taken with the negative root and $1 + q_2$ with the positive root, and *vice versa*. The other formulæ to calculate this curve are :—$r = \dfrac{6(\beta_2 - \beta_1 - 1)}{6 + 3\beta_1 - 2\beta_2}$, also $l = \frac{1}{2}\sqrt{\mu_2}\sqrt{\beta_1(r+2)^2 + 16(r+1)}$. Further, the root

$$1 - q_1 = -\frac{r}{2} + \frac{r(r+2)}{2}\sqrt{\frac{\beta_1}{\beta_1(r+2)^2 + 16(r+1)}},$$ while the root

$$1 + q_2 = -\frac{r}{2} - \frac{r(r+2)}{2}\sqrt{\frac{\beta_1}{\beta_1(r+2)^2 + 16(r+1)}}.$$

The skewness $= \frac{1}{2}\sqrt{\beta_1}\dfrac{r+2}{r+2}$, and $y_0 = \dfrac{Nl^{q_1-q_2-1}\Gamma(q_1)}{\Gamma(q_1-q_2-1)\Gamma(q_2+1)}$. The origin of

the curve $=$ mean $-\frac{l(q_1-1)}{q_1-q_2-2}$, and the mode $=$ mean $-\frac{1}{2}\cdot\frac{\mu_3}{\mu_2}\cdot\frac{r+2}{r+2}$.

The general mode of working out these curves will follow the lines explained for Type I., and, except when specially stated to be otherwise, the values of the various moments and functions must be determined as in Type I.

Correlation.—In the preceding section we have been considering the type and variation about the type in the case of a single character, but where there are two or more characters the relation between their magnitudes is correlated variation. Thus, two measurable characteristics, A and B, are said to be correlated, when, with different values, x of A, certain values of B are relatively more likely to occur with the value x than others. Put in another way, any abmodality of the one is accompanied by a corresponding abmodality of the other or others.

The measurement of correlation is applicable to cases where the distribution of variates is either symmetrical or skew, and the principles upon which the measurement of correlated variation rests are these. If we take a number of individuals at random we find that the mean magnitude of any character is equal to the mean magnitude of this character in the whole population. If there is any deviation from the mean of the whole population in any group of individuals, this deviation implies a selection. Suppose we select individuals on the basis of one character A, called the *subject*, and also any closely correlated character B, called the *relative*, we shall find that, if these characters be perfectly correlated, the index of abmodality $\left(\frac{x}{\sigma}\right)$ of any class of B will be as great as that of the corresponding class of A, or $\frac{\text{index abmodality of relative class}}{\text{index abmodality of subject class}}=1$. If there is no correlation, then whatever the value of the abmodality index of the subject, that of the relative will be zero, and the *coefficient of correlation*, commonly written r, will be 0.

The simplest case for measuring correlation is when the characters or organs are each measured in the same unit, and have the same mean and standard deviation. If we pluck a pod from a pea-plant, and it has 7 peas, while a pod from a second plant has 13 peas, then a third pod from a third plant would probably have 10 peas, as that is the mode of pea-pods. If the third pea-plant happened to be identical with the first or second plant, the most probable number of peas in the pod would not be 10 but some number nearer to 7 in the first case or to 13 in the second. How much nearer can only be answered by the calculation of correlation. The basis of the theory of correlation will be seen from the following case. Imagine 11,026 pea-pods gathered in pairs, each pair belonging to the same plant. Select out of these pairs those in which one pod has 5 peas and assume the number to be 12 such cases; in 8 of them there were 6 peas and in 4 of them 7 peas in the other pod of the pair. Similarly, we can take out the pairs in which there are 6 peas in one pod or member, say there are 133 of them; in like manner take out the pairs having one member with 7 peas, assume them to total 661. Continue to enumerate all the pairs, increasing by one the number of peas in one member of the pair. In so doing, it will be manifest that as we increase the number of peas in one member of a pair, the second has on the average a less value, regressing slightly to the mean of the general population or number of individuals. The following Table will probably make this more intelligible.

If we take any column, say the 11 column, we have a frequency distribution under it corresponding to the frequency with which pods of 6, 7, 8, &c.,

peas were found on the same plant with pods of 11 peas in the 11,026 pods included in the Table. At the bottom of each column is given the mean number of peas for that column, and the mean of the whole series is 10·04. Thus the mean of the 11 column is not 11 but 10·73, in other words, the pods associated on the same plant with an 11 pod have not a mean of 11, nor the general racial mean of 10·04 but regress from 11 towards the general mean.

Number of Peas in Second Pod.	Number of Peas in First Pod.												Total.
	5	6	7	8	9	10	11	12	13	14	15	16	
5	—	8	4	—	—	—	—	—	—	—	—	—	12
6	8	38	46	23	11	5	2	—	—	—	—	—	133
7	4	46	184	163	146	78	31	8	1	—	—	—	661
8	—	23	163	390	398	279	111	75	32	4	—	—	1,475
9	—	11	146	398	554	415	250	161	68	9	5	—	2,017
10	—	5	78	279	415	514	520	240	112	27	10	—	2,200
11	—	2	31	111	250	520	770	366	160	52	9	—	2,271
12	—	—	8	75	161	240	366	252	178	35	12	—	1,327
13	—	—	1	32	68	112	160	178	92	23	11	—	677
14	—	—	—	4	9	27	52	35	23	28	12	—	190
15	—	—	—	—	5	10	9	12	11	12	4	—	63
16	—	—	—	—	—	—	—	—	—	—	—	—	—
Totals .	12	133	661	1475	2017	2200	2271	1327	677	190	63	—	11,026
Means .	6·33	7·11	8·22	9·06	9·51	10·12	10·73	10·96	11·19	11·82	12·05	—	10·04

Any ambiguity attaching to the figures will probably be removed by a consideration of Fig. 169, in which the scale on the horizontal line indicates the number of peas in the selected pod, while along the vertical lines are marked points, 5*a*, 6*b*, 7*c*, 8*d*, 9*e*, &c., equal to the successive means 6·33, 7·11, 8·22, 9·06, 9·51, &c., of the associated pods. If a straight line be fitted closely upon these points, we obtain the *line of regression*, A B. When all the points lie on the line, the regression and correlation are said to be *linear*, otherwise they are *skew*. The frequency given for any group of pods associated with a selected pod is termed an *array*. Thus, 8, 38, 46, 23, 11, 5, 2 is the array corresponding to 6. If there be no regression at all, then the mean of the 6 array will be 6, of the 7 array 7,

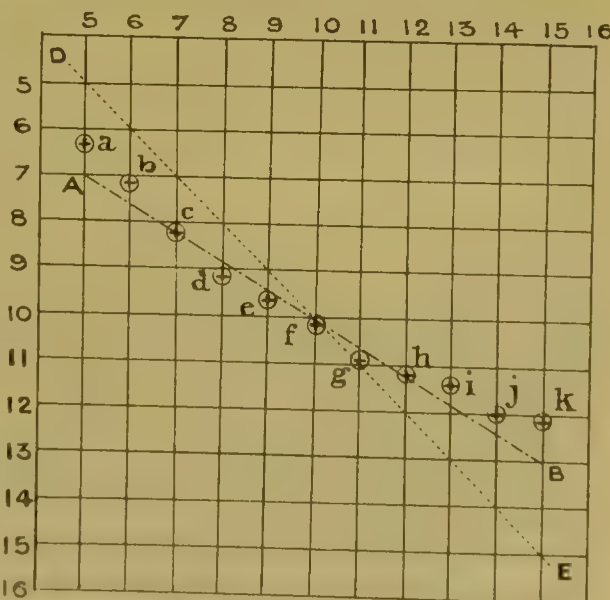


Fig. 169.—Regression Line.

and so on; the regression line becoming accordingly the diagonal line DE. Put in another way, when the regression is zero, the slope of the regression line is unity. If AB, on the other hand, were horizontal, the mean of each

array would be 10·04, so that there would be no correlation but perfect regression. For this reason, the steepness of the line AB is a measure of the regression or amount of the correlation shown in the pairs of pea-pods. In this particular case the coefficient of correlation or $r = 0·56$, or a correlation of 0·56 represents the degree of resemblance of like parts in the individual pea-plant.

If we take the standard deviation σ of an array about the corresponding point on the line of regression, then the mean value of the standard deviation for all the arrays, σ_2 will be $\sigma_2 (1 - r^2)$; further, if the regression be truly linear, and we assume that variability takes its rise in an indefinitely great number of groups which are independent of each other, then $\sigma\sqrt{1 - r^2}$ is the standard deviation of each array about its mean, and this is the same for all arrays. In this case we can obtain the variability of an array from the racial variability by multiplying by the quantity $\sqrt{1 - r^2}$. Thus, the higher the correlation, the more surely we can predict from one member what the value of the associated member will be. This is what Pearson calls the "transition of correlation into causation"; causation telling us that B will accompany A, the correlation indicating the proportion of cases of that accompaniment; and as r approaches unity this will be more and more approximate to 100 per cent.*

Galton has suggested a graphic method of determining the coefficient of correlation. Draw perpendicular axes x and y on co-ordinate ruled paper; locate a series of points from the pairs of indices of abmodality of the relative and subject corresponding to each subject class. The indices of the subjects are laid off as abscissæ, the indices of the relatives as ordinates. Get another set of points by making a second correlation table, regarding character B as subject and character A as relative. Then draw a straight line through these points so as to divide the region occupied by them into two halves. The tangent of the angle made by the last line with the horizontal axis is the index of correlation.

So far we have been dealing with two associated like organs from the same individual, but suppose we conceive ourselves to be dealing with dissimilar organs not having the same standard deviation. If we say the standard deviation of A is σ and that of B is σ_1, then the slope of the regression line is simply altered in the ratio of $\frac{\sigma_1}{\sigma}$ and if we call it r as in the first case, it now becomes $\frac{\sigma_1}{\sigma} r$. This is the coefficient of regression and may take any value between 0 and ± 1; if it is positive the characters increase together; if negative, as one increases the other decreases. Put into other words, the probable deviation of a second organ from its mean is the product of the coefficient of regression into the observed deviation of the first organ from its mean.

We have now the outline of a numerical method of appreciating correlation. Its stages are briefly as follows:—(*a*) Measure or count some character in pairs of organs of the same or different individuals, for, say, 1000 cases. (*b*) Prepare a correlation table by selecting successively organs of a given size in one member of the pair and forming the array of the organs in the other member of such pairs. (*c*) Add up the columns and rows of this table so as to form a column and row of totals as given in the Table relating to the pea-pods; the means and standard deviations of the column totals and the

* The reader should bear in mind that although all causation may be correlation, the converse is not necessarily true, because correlation does not always predict causation. See Pearson's *Grammar of Science*, p. 405 *et seq.*, and the discussion on "Evolution."

row totals give the types and variabilities of the two organs in the whole population. Let these be μ, μ_1, and σ, σ_1. (*d*) Find the means of each separate column array; then the best fitting straight line drawn through these means, when plotted as in Fig. 169, is the line of regression for the second organ on the first, and its slope is $\frac{\sigma_1}{\sigma} r$. Similarly, the line of regression for the first organ on the second may be found from the plotted means of the rows, and its slope is $\frac{\sigma}{\sigma_1} r$. If x and y be the deviations from their means of the two organs of an associated pair, then $\mu + x$ will be the value of the first organ in one member of the pair, and $\mu_1 + y$ the value of the second organ in the other member of the pair. If now we take the average value for all associated pairs of the product $x \times y$ and divide this by the product of the standard deviations $\sigma \times \sigma_1$ the result is r, the correlation coefficient.

For instance let us take the accompanying table by Greenwood * dealing with the case of hearts and kidneys in respect of weight. A table of pairs is formed, and the mean and the standard deviation of each variable calculated. The deviations of each sub-group from the means of the respective organs are multiplied together and by the number of individuals in the sub-group. If the symbol of summation be Σ, then $r = \frac{\Sigma(xy)}{n\sigma\sigma_1}$, where n is the total number of pairs and σ and σ_1 the standard deviations of the variables.

	Hearts in Ounces. Mean 11·24 oz., S.D. = 1·946 oz.									Totals.
Kidneys in ounces. Mean = 12·01 oz., S.D. = 2·016 oz.	7·625	8·625	9·625	10·625	11·625	12·625	13·625	14·625	15·625	
7·625	1	3	—	2	2	1	—	—	—	9
8·625	1	6	5	1	3	1	—	—	—	17
9·625	7	7	6	14	6	4	3	1	1	49
10·625	2	8	23	17	11	4	2	2	1	70
11·625	1	5	11	22	19	12	7	3	1	81
12·625	1	4	17	12	11	13	8	1	1	68
13·625	3	2	8	7	12	9	7	4	2	54
14·625	1	—	4	3	5	5	8	2	5	33
15·625	1	1	1	1	4	2	7	4	3	24
16·625	—	—	—	1	2	1	—	2	1	7
17·625	—	—	—	—	1	—	—	—	—	1
Totals . .	18	36	75	80	76	52	42	19	15	413

In this example, the deviations of the first sub-group from the means of the relative and subject are −3·615 and −4·385; of the second, −2·615 and 3·385; of the third −1·615 and −2·385 and so on; the result being that to get r many products have to be found in the numerator, in fact, as many sets of products as there are entries in the body of the table. A portion of these products to be calculated is indicated below; while the denominator will be clearly $413 \times 1{\cdot}946 \times 2{\cdot}016$.

$$-4{\cdot}385 \times \left| \begin{array}{l} -3{\cdot}615 \times 1 \\ 2{\cdot}615 \times 3 \\ 0{\cdot}615 \times 2 \\ 0{\cdot}385 \times 2 \\ 1{\cdot}385 \times 1 \end{array} \right. \qquad -3{\cdot}385 \times \left| \begin{array}{l} -3{\cdot}615 \times 1 \\ -2{\cdot}615 \times 6 \\ -1{\cdot}615 \times 5 \\ 0{\cdot}615 \times 1 \\ 0{\cdot}385 \times 3 \\ 1{\cdot}385 \times 1 \end{array} \right.$$

* Greenwood: see *Biometrika*, vol. iii. p. 78.

The result is $r = 0{\cdot}4$ and as the *probable error* of r or $\mathrm{E}r = \frac{0{\cdot}6745\,(1-r^2)}{\sqrt{n}}$ we can say that the correlation coefficient is 0·4 with a probable error of ±0·0278.

The application of correlation in this manner enables us to reconstruct from one organ the probable value of the second, or in the case of the full mathematical theory the value of one organ from any number of known organs. Thus, if we pick up one or more bones of a prehistoric man we can reconstruct from it by calculation other parts of the skeleton. The numerical value of the correlation for a considerable number of characters in man, in fishes, the crustacea and a few plants has been determined. As typical of a few correlation coefficients in man we may quote the following:—femur and tibia 0·81, femur and humerus 0·84, weight and length of babies 0·63, stature and forearm 0·37, strength of pull and weight 0·35 to 0·52. The method can always be used when the characters are quantitatively measurable, and instances of its application to medical problems are numerous; thus the correlation between birth-rate and cancer death-rate is − 0·563 with an error of ± 0·089; between phthisis prevalence and birth-rate the correlation is 0·594 or ± 0·084; similarly correlation between acute rheumatism hospital admissions and rainfall in August is given as − 0·472, with a probable error of ± 0·094.

Male Pedigrees. Parents.			Female Pedigrees. Parents.		
Offspring.	Tuberculous.	Non-tuberculous.	Offspring.	Tuberculous.	Non-tuberculous.
Tuberculous .	$49+y$	361	Tuberculous .	$107+y$	509
Non-tuberculous	$108-y$	x	Non-tuberculous	$207-y$	x

Some recent work by Karl Pearson * on the inheritance of pulmonary consumption affords further instance of the value of these methods in hygienic inquiries. Working on the very full records of 384 stocks in which cases of pulmonary tuberculosis had occurred, Pearson shows that the mean age of onset for men was 29·1 years with a standard deviation of 9·8 years; for women the onset is at 25·3 years with a standard deviation of 8·6. In determining the correlation between the occurrence of pulmonary tuberculosis in parents and offspring, the data were arranged in the foregoing fourfold Table. The numbers represent the actual data available; each child is entered twice, once with each parent; x represents the number of non-tuberculous offspring of non-tuberculous parents which are not provided by the records, but which, on the basis of a random sample of the general population, would be associated with this amount of tuberculous material. The unknown y represents the correction necessary owing to the fact that all the offspring had not passed the danger zone, roughly from the fourteenth to the fortieth year, and might develop the disease later. From Thompson's figures † and records of families with completed tuberculous history, it may be said that slightly more than half the offspring of a tuberculous parentage are tuberculous. Accordingly, $49+y=108-y$, or $y=30$ for males, and $107+y=207-y$, or $y=50$ for females. Substituting these values for y we get 440 total tuberculous male offspring and $78+x$ non-tuberculous male offspring,

* Pearson: "A First Study of the Statistics of Pulmonary Tuberculosis," *Drapers' Company Research Memoirs*, London, 1907.

† Thompson: *Family Phthisis*, p. 45.

or total male offspring $518+x$. On the female side, the tuberculous total is 666 and the non-tuberculous $157+x$, or a total of $823+x$.

Quite 10 per cent. of the people may be said to be affected with pulmonary tuberculosis, and assuming that the data are a normal sample of the population, we can give x a value thus :—$440 = \frac{1}{10}(518 + x)$ or $x = 3882$ for males and $666 = \frac{1}{10}(823 + x)$ or $x = 5837$ for females. The Table can be now made to take this form :—

Male Pedigrees.	Parents.			Female Pedigrees.	Parents.		
Offspring.	Tuberculous.	Non-tuberculous.	Totals.	Offspring.	Tuberculous.	Non-tuberculous.	Totals.
Tuberculous .	79	361	440	Tuberculous .	157	509	666
Non-tuberculous . .	78	3882	3960	Non-tuberculous .	157	5837	5994
Totals .	157	4243	4400	Totals .	314	6346	6660

On these assumptions, Pearson works out the correlation coefficient to be 0·59 for males and 0·62 for female pedigrees. If y be put at 0, giving a lower limit to the intensity of inheritance, then r becomes 0·33 and 0·44 respectively. If 13 instead of 10 per cent. of the whole population are supposed to be tuberculous, the values are 0·55 and 0·58. From this mathematical study the inference to be drawn is that " the diathesis of pulmonary tuberculosis is undoubtedly inherited, and that the intensity of this inheritance is comparable with that found for normal physical characters in man."

	Cicatrix.	Recoveries.	Deaths.	Total.
Degree of effective Vaccination	Present .	3951	200	4151
	Absent .	278	274	552
Total . . .		4229	474	4703

A variety of other examples could be quoted showing the importance of this method in the study of vital statistics and eugenics,* but it must be remembered that its application is equally possible in inquiries where the characters can hardly be measured in terms of a quantitative scale. A typical case is that where we wish to obtain an exact measure of the prophylactic value of vaccination, but are unable to reduce either the degrees of effective vaccination or the varying severity of small-pox to terms of an exact quantitative scale. We can, however, express our returns into a few broad classes as distinguished from a number of small, finely graduated classes. We see this in the foregoing Table† from which r or the correlation between degree of effective vaccination and strength to resist small-pox was found to be 0·7692, with a probable error of ±0·0124, which is a very high value. Similar inquiries have been made in regard to the value of

* The student should consult Pearson on " Insane Diathesis," *Brit. Med. Journal*, 1905, vol. i. p. 1176; *also* Schuster on " Hereditary Deafness," *Biometrika*, vol. iv. p. 466; *also* Lea and Pearson on " Eye Colour," *Philosoph. Trans.*, 195 A. p. 106.

† Macdonell, *Biometrika*, vol. i. p. 375; *also* vol. iv. p. 505, and vol. v. p. 361. *See also* Pearson, *Philosoph. Trans.*, 193 A. p. 43

antitoxin serum in diphtheria. The correlation works out at 0·4708 or ±0·0292.

Contingency.—In dealing with the problem of the relationship of attributes or characters not capable of quantitative measurement, we have classified the two attributes into a number of groups, such as A_1 A_2 . . . A_s, and B_1, B_2 . . . B_t. In this way a Table can be formed containing s columns and t rows, or $s \times t$ compartments. In simple cases of association, s and t are both equal to two, and we have a simple fourfold division; but in other cases, such as when we classify the human eye into colours or table the colours of dogs or horses, we may have to correlate some dozen classes for each attribute. In his recent mathematical work on such things as temper in man, eye colour in man, and hair colour in man and animals, Pearson has shown that the elaborate classifying of attributes is a matter of no importance when we are dealing with correlation, but that their relationship to one another can be explained by the theory of *contingency*. Contingency he describes as a measure of the total deviation of any classification from independent probability.*

The following statement will explain the nature of independent probability. If p be the probability of any event, and q be the probability of any second event, then these two events are independent, if the probability of the combined event be $p \times q$. Let A be an attribute or character, and let it be classified into group A_1, A_2 . . . A_s, and let the total number of individuals examined be N, the total numbers falling into the groups n_1, n_2 . . . n_s, respectively. Clearly the probability of any individual falling into one of these groups will be n_1/N, n_2/N . . . n_s/N respectively. Suppose the same population N to be classified by another attribute into the groups B_1, B_2 . . . B_t, and the group frequencies of the N individuals to be m_1, m_2 . . . m_t respectively. The probability of an individual falling into these groups will be respectively m_1/N, m_2/N. m_3/N, . . . m_t/N. Accordingly the number of combinations of B_v with A_u to be expected on the theory of independent probability if N pairs of attributes are examined is $N \times \frac{n_u}{N} \times \frac{m_v}{N} = \frac{n_u m_v}{N}$ or call it ν_{uv}. If we assume the number actually observed to be n_{uv}, then $n_{uv} - \frac{n_u m_v}{N}$ is $n_{uv} - \nu_{uv}$. It is obvious that the total deviation of the whole classification of the attributes from independent probability must be some function of the $n_{uv} - \nu_{uv}$ quantities for the whole Table. As we have explained, any measure of this is a measure of its contingency, and the greater the contingency the greater must be the association or correlation between the two attributes, as this correlation is but a measure from another standpoint of the degree of deviation from independence of occurrence.

Pearson † has shown that if $m^1{}_1$, $m^1{}_2$, $m^1{}_3$ . . . $m^1{}_n$ be any system of observed frequencies, and m_1, m_2, m_3, . . . m_n be any system of theoretical frequencies, then $\Sigma \left\{ \frac{(m^1{}_q - m_q)^2}{m_q} \right\}$, or the sum of the squares of the differences between each pair of figures divided by the frequency of the independent probables gives a measure of the position that is indicated by the probability of the particular distribution. Let this be called χ^2. If we want to measure contingency, we want really to measure the deviation of the observed results from independent probability, and if we take m_1, m_2, m_3 . . . m_n to correspond to the

* Pearson: "On the Theory of Contingency," *Drapers' Company Research Memoirs*, No. XIII., 1904.

† Pearson: "On Deviations from the Probable in a Correlated System of Variables," *Philosoph. Magazine*, July 1900, p. 157.

system $\nu_{..}$ and $m'_1, m'_2, m'_3 \ldots m'_n$ to correspond to the actually observed system $n_{..}$, then $\chi^2 = \Sigma\left\{\frac{(n_{..} - \nu_{..})^2}{\nu_{..}}\right\}$; if this result be now divided by the whole number of observations, we get χ^2/N, or, as Pearson calls it, the *mean square contingency*, usually written ϕ^2. Further, it has been shown by Pearson that, mathematically, the mean square contingency is really $r^2/(1-r^2)$, or $r = \sqrt{\frac{\phi^2}{1+\phi^2}}$, and that the relationship between mean square contingency and correlation in the case of normal frequency is of a simple character—so much so that with sufficiently fine grouping, say twenty sub-groups, the value obtained in this way approximates to that of r found by the ordinary method. The probable error of the coefficient of contingency may be taken as approximately one and a third times that of r; hence when a correlation table can be formed and worked there is little doubt that it is safer to do so. While r is spoken of as the coefficient of correlation, the value of $\sqrt{\frac{\phi^2}{1+\phi^2}}$ is the coefficient of contingency.

Weight of Kidneys in Ounces.	Weight of Hearts in Ounces.									Totals.
	7·625	8·625	9·625	10·625	11·625	12·625	13·625	14·625	15·625	
7·625	1	3	—	2	2	1	—	—	—	9
	0.4	0.78	1.63	1.74	1.65	1.13	0.9	0.4	0.32	
8·625	1	6	5	1	3	1	—	—	—	17
	0.74	1.48	3	3.3	3.1	2.14	1.7	0.78	0.6	
9·625	7	7	6	14	6	4	3	1	1	49
	2.13	4.27	8.9	9.5	9	6.17	5	2.2	1.7	
10·625	2	8	23	17	11	4	2	2	1	70
	3	6	12.7	13.56	12.8	8.8	7.1	3.2	2.5	
11·625	1	5	11	22	19	12	7	3	1	81
	3.5	7	14.7	15.6	14.9	10.2	8.2	3.8	2.6	
12·625	1	4	17	12	11	13	8	1	1	68
	3	6	12.3	13.1	12.4	8.56	6.9	3.1	2.3	
13·625	3	2	8	7	12	9	7	4	2	54
	2.3	4.6	9.8	10.5	9.9	6.8	5.5	2.6	1.7	
14·625	1	—	4	3	5	5	8	2	5	33
	1.4	2.8	5.9	6.3	6	4.1	3.3	1.5	1	
15·625	1	1	1	1	4	2	7	4	3	24
	1	2	4.3	4.6	4.4	3	2.4	1.1	0.86	
16·625	—	—	—	1	2	1	—	2	1	7
	0.3	0.6	1.2	1.3	1.2	0.8	0.7	0.3	0.22	
17·625	—	—	—	—	1	—	—	—	—	1
	0.04	0.08	0.18	0.19	0.18	0.12	0.1	0.04	0.03	
Totals .	18	36	75	80	76	52	42	19	15	413

The manner of working out the coefficient of contingency will be perhaps more apparent from an example. Let us take the correlation table given on page 823, relating to hearts and kidneys; this is now given slightly reconstructed, in which the figures in small type are the independent probabilities. The "chance" or probability of a kidney of a given weight occurring in each group will be in the proportion of the total of the series to the totals of the rows, or n/N, and the independent probabilities were found by multiplying the probabilities or chances of a kidney occurring in each group by the totals for each group or column of hearts. Thus the first column of independent probabilities would be $18 \times \frac{9}{413}$, $18 \times \frac{17}{413}$, $18 \times \frac{49}{413}$,

$18 \times \frac{70}{413}$, and so on. Proceeding next to take the differences between the independent probabilities and the observed frequencies, squaring and dividing each by the independent probability frequency, then summing and dividing by the total frequency, we find ϕ^2 to be 0·216, whence $\sqrt{\frac{\phi^2}{1+\phi^2}}$, or the coefficient of contingency, is 0·46—a result approximately close to the correlation coefficient. The probable error of this coefficient is $\pm 0 \cdot 0376$.

Probability.—The fundamental object of all statistical inquiries being to explain or reconcile cause with effect, it is necessary to appreciate the scientific value of the word cause. As originating or enforcing a particular sequence of perceptions or events, the term cause is scientifically meaningless. But if we use it as marking a stage in the routine of experience, and not one in a routine of necessity, we can get a clear and valuable conception of the real meaning of the word cause; so much so, that we can affirm that there is nothing in cause which compels us of inherent necessity to predict the effect. Effect is associated with cause simply as a result of past direct or indirect experience; while experience may be defined as the routine or uniformity with which sequences of perceptions are repeated. If we, further, analyse our field of perceptions, we find that if something has once been perceived it will under precisely the same circumstances be again perceived. Our appreciation or conviction of this routine of perceptions is not a certainty or provable, but merely that it is probable. The problem, therefore, comes to this:—A certain order of perceptions has been experienced in the past; what is the probability that the perceptions will repeat themselves in the same order in the future?

When we come to express the nature of probability mathematically, we find that the probability that an event, which has occurred p times and has not hitherto failed, will occur again is represented by the fraction $\frac{p+1}{p+2}$. Or we can put the question in this way:—p different sequences of perception have been found to follow a certain routine, none ever failing; what is the probability that the $(p+1)$th sequence of perceptions will have a routine? The odds are $(p+1)$ to one in favour of the new sequence having a routine. Similarly, if an event has happened p times and failed q times, then the probability that it will happen the next time is $\frac{p+1}{p+q+2}$, or the odds in favour of its happening are $p+1$ to $q+1$.

Suppose we take a coin and toss it; then the chances that head or tail will be uppermost are exactly equal. Taking unity to denote certainty, we can say that the probability of a head equals $\frac{1}{2}$. If we toss it again, the chances of a head will be still $\frac{1}{2}$. Since in two throws there has been an equal chance of the four combinations, head, head; tail, tail; head, tail; tail, head, it follows that the recurrence of head has only a probability of $\frac{1}{2} \times \frac{1}{2}$, or $\frac{1}{4}$. Similarly, the probability that three heads will be uppermost in succession will be $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, or $\frac{1}{8}$; that is, the odds are seven to one against a triple recurrence. If we extend this to twenty recurrences of heads, there is an overwhelming probability against a succession of recurrences without a break. Instead of the coin, let us imagine a bag, and put into it an equal number of black and white balls. The probability of a random drawing resulting in a white ball will be $\frac{1}{2}$, and this will remain so at all drawings provided the balls be returned to the bag after each drawing. But suppose there is not an equal number of white and black balls in the bag. Say p is the probability of a white ball being drawn and q the prob-

ability of a black ball being drawn, the ball being returned to the bag after each withdrawal; then the probabilities of its happening once, twice, and so on out of n trials are given by the terms of the expansion $(p+q)^n$; or if we have N cases, the terms of $N(p+q)_n$ give the frequency distribution of the N cases into n groups. Thus the chances of getting r, $r-1$, $r-2$, or 0 black balls from a bag containing pn black and qn white balls when r balls are drawn are given by the successive terms of the following series:

$$\frac{pn(pn-1)\ldots(pn-r+1)}{n(n-1)\ldots(n-r+1)} = r \text{ are all black.}$$

$$\frac{pn(pn-1)\ldots(pn-r+1)}{n(n-1)\ldots(n-r+1)} \cdot \frac{rqn}{pn-r+1} = r-1, \text{ or two are black.}$$

$$\frac{pn(pn-1)\ldots(pn-r+1)}{n(n-1)\ldots(n-r+1)} \cdot \frac{rqn}{pn-r+2} = r-2, \text{ or one is black.}$$

$$\frac{qn(qn-1)\ldots(qn-r+1)}{n(n-1)\ldots(n-r+1)} = r-3, \text{ or none are black.}$$

A numerical example may help to make this clearer. Suppose a bag contains seven balls, of which four are black and three white; then if three balls are drawn the probability that all will be black is 0·114, or 8·7 to 1; that two will be black is 0·513, or 1·9 to 1; that one will be black is 0·342, or 2·9 to 1; that none will be black is 0·028, or 35·7 to 1. It will be obvious that $n = 7$, $pn = 4$, $qn = 3$, and $r = 3$.*

Probable Error.—In the previous sections of this chapter we have assumed that the means, standard deviations, moments, constants, and coefficients of correlation and contingency obtained from statistics give an exact measure between two functions. This, however, is not really the case. Were we able to measure the whole population or make an infinite number of trials, the statistical constants obtained would be accurate; but in practice we can only get a sample. What, we may ask, then, is the chance that in a second sample of the same material the constants deduced will not differ from those calculated on the basis of the first sample by more than a specified amount? In practice we determine this by measuring the deviation which is as likely as not to occur of those constants, and this is called the "probable error." This probable error is really another function, and is practically 0·67449 times the standard deviation.

The theory of the probable error and the connection between it and the standard deviation is developed from the normal curve of error, and gives that value (p) of x which divides the part of the normal curve representing positive errors into two equal portions. Its proof is, however, of a complicated nature, and unsuitable for insertion in the present work.

It is clear that the magnitude of the probable error is a criterion of the weight to be attached to any statistical constant, and any statistical constants unaccompanied by their probable errors are of no scientific importance. Since the exact degree of improbability to be regarded as decisive is a matter of individual opinion, the general rule followed by statisticians when considering probable errors is that unless a result exceeds the expected by two or three times the probable error it is not safe to assume that the particular case differs from the expected result. This value is of considerable use in statistical work, and it may be of interest to see its application to an example.

* The reader who wishes to study this question further should consult Todhunter's *Algebra*; *also* Todhunter's *History of the Theory of Probability*; *also* Galloway's *A Treatise on Probability*, Edinburgh, 1839; *also* Venn, *On the Logic of Chance*, London, 1866. *See also* Pearson's *Grammar of Science*, London, 1900.

Assume a simple case wherein it is wished to find the probable error of an event happening mp times when m trials are made and p is the probability of the event happening and q of its failing. The whole series is given by $(p+q)^m = p^m + mp^{m-1}q + \ldots + q^m$. The standard deviation is $\sqrt{mpq}$, and the probable error is $0{\cdot}67449\sqrt{mpq}$. Take another case: If 51,350 out of 100,000 children proved to be males in a certain township, would it be safe to base on the statistics any theory connected with the variation from the usual probability that the number of male children born is to the number of females born as 1050 is to 1000? Clearly the expected result is 51,220; therefore the probable error is $0{\cdot}67449\sqrt{100{,}000\,\frac{1050}{2050}\cdot\frac{950}{2050}}$, or $\pm 103{\cdot}9$. The difference between the actual case and the expected result was 130, and as this is but one and a quarter times the probable error no definite conclusions can be based on the divergence from the result. Had the number of cases been ten millions, then the probable error would have been 1039 and the actual difference 13,000. This would have been sufficient evidence for the conclusion that the ratio 1050 to 1000 did not fit the particular case.

It is unnecessary here to go into further detail as to the calculation of probable errors. Formulæ have been obtained for the errors of all important constants, among which may be mentioned the following: The *probable error of the mean* is $\pm 0{\cdot}67449 \times \frac{\text{standard deviation}}{\text{square root of the number of variates}}$. The *probable error of the median* is $\pm 0{\cdot}84535 \times$ standard deviation $\div$ square root of the number of variates. The *probable difference between two averages* of which the probable errors are known is the square root of the sum of the squared probable errors. The *probable error of the standard deviation* is $\pm 0{\cdot}67449 \frac{\text{standard deviation}}{\text{square root of twice the number of variates}}$. By substituting the coefficient of correlation for the standard deviation, the same formula will give the *probable error of the coefficient of correlation.*

Recognising that the probable error (E) is a pair of values lying one above and the other below the value determined, we can say that there is an even chance that the true value lies between these limits. The chances that the true value lies within ± 2E are 4·5 to 1, within ± 3E are 21 to 1, within ± 4E are 142 to 1, and within $\pm$ 5E are 1310 to 1.

CHAPTER XIX

CLIMATE AND METEOROLOGY.

THE word climate (κλίμα, a slope, from κλίνειν, to incline) originally signified that obliquity of the sphere with respect to the horizon from which results the inequality of day and night. In its modern acceptation it may be taken to mean the sum of all the meteorological conditions of a place or region, including not only those of temperature, but the meteorological conditions generally, so far as these exercise an influence on the animal and vegetable kingdoms. There are four principal factors in the production of the climate of any place or country :—(1) Distance from the equator ; (2) Height above the sea ; (3) Distance from the sea ; (4) Prevailing winds.

With regard generally to the effect of climate on human life, it would seem certain that the facility of obtaining food, rather than any of the immediate effects of climate, regulates the location of men and the amount of population. The human frame seems to acquire in time a wonderful power of adaptation. Peculiarities of race, indeed, arising no one knows how, but probably from the combined influences of climate, food, and customs, acting through many ages, appear to have more effect on stature, health, and duration of life than climate alone. Still, it would seem probable that, in climatic conditions so diverse, there arise some special differences of structure which are most marked in the skin, but may possibly involve other organs.

How soon the body, when it has become accustomed by length of residence for successive generations to one climate, can accommodate itself to, or bear the conditions of, the climate of another widely different place, is a question which can only be answered when the influences of climate are better known. The hypothesis of " acclimatisation " implies that there is at first an injurious effect produced, and then an accommodation of the body to the new conditions within a very limited time ; that, for example, the dweller in northern zones passing into the tropics, although he at first suffers, acquires in a few years some special constitution which relieves him from the injurious consequences which, it is supposed, the change at first brought with it. It may seem a bold thing to question the commonly received opinion that a tropical climate is injurious to a northern constitution, but there are some striking facts which it is difficult to reconcile with such an opinion. The army experience shows that, both in the West Indies and in India, the mortality and morbidity of the soldier has been decreasing gradually. In Algeria, the experience of the French is similar. As the climate and the places are the same, and the soldiers are of the same race, what has removed the dangers which formerly made the sickness threefold and the mortality tenfold the corresponding ratios at home? The explanation is that the sanitary precautions which are so efficacious in England or France have been as useful in the East and West Indies and in Algeria. Proper food, good water and rational habits and sensible clothing have been supplied, and in proportion as they have been so, the deadly effects attributed to climate have

disappeared. The effect of a tropical climate is, so to speak, relative. Take away sanitary defects and let the mode of living be a proper one, then the European does not die sooner in the tropics than at home.

It must be said, however, that an element of uncertainty may be pointed out here. In our tropical possessions the European remains now only for short periods, and during this time he may be for some years on the hills, or at any rate in elevated spots. The old statistical reports of the army pointed out that the mortality in the West Indies augmented regularly with prolongation of service, and it may be said that, after all, the lessened sickness and mortality in the tropics is owing, in some degree, to avoidance by short service of the influence of climate. But as the whole long service was constantly passed under the unfavourable sanitary conditions now removed, it does not follow that the inference to be drawn from the statistical evidence as to length of service is really correct.

Facts prove, then, that under favourable sanitary conditions (general and personal) Europeans, during short service, may be as healthy as at home, as far as shown by tables of sickness and mortality, and it is not certain that long service brings with it different results.

It may, however, be urged that, admitting that a tropical climate, *per se*, may not increase sickness or mortality during the most vigorous years of life, it may yet really diminish health. This practically is the gist of the whole relationship between climate and health, so that a convenient division of the subject is into :—(1) How far is climate injurious to health ? and (2) How far is it beneficial to health ?

In attempting to answer these questions, it is necessary to inquire what is known of the effects of climatic agencies on the body. The influences of locality and climate, as far as they are connected with soil and water, have already been sufficiently discussed elsewhere. Setting aside the question of the amount of sunlight, and the actual chemical composition of the atmosphere, the chief climatic conditions or elements which influence health are temperature, humidity, air movement or wind, and atmospheric pressure ; to these must be added the presence of animals or insects depending upon these physical conditions.

Influence of Temperature upon Health.—Although the effects of heat cannot be dissociated from the other conditions, it is necessary, however briefly, to notice them. The effect of a certain degree of temperature on the vital processes of a race dwelling generation after generation on the same spot is a question which has as yet been but imperfectly answered. The problem is generally presented to us under the form of a dweller in a temperate zone proceeding to countries either colder or hotter than his own. In this restricted sense we shall now consider it.

The effects of heat exceeding the temperate standard must be distinguished according to origin ; radiant heat, or the direct rays of the sun and non-radiant heat or that of the atmosphere. In the latter case, in addition to heat, there is more or less rarefaction of the air, and also coincident conditions of humidity and movement of the air, which must be taken into account. The influence, again, of sudden transitions from heat to cold, or the reverse, has to be considered. Europeans from temperate climates flourish, apparently, in countries not much hotter than their own, as in some parts of Australia, New Zealand, and New Caledonia, where the vigour of the race has improved. But there is a general impression that they do not flourish in countries much hotter, *i.e.*, with a yearly mean of 20° F. higher, as in many parts of India ; that the race dwindles, and finally dies out ; and, therefore, that no acclimatisation of race

occurs. And certainly it would appear that in India there is evidence to show that the pure race, if not intermixed with the native, does not reach beyond the third generation. Yet it seems only right to say that so many circumstances besides heat and the other elements of climate have been acting on the English race in India, that any conclusion opposed to acclimatisation must be considered as based on scanty evidence. We have not gauged on a large scale the effects of climate pure and simple, uncomplicated with malaria, bad diet, and other influences adverse to health and longevity.

(*a*) *Influence of the Direct Rays of the Sun.*—It is not yet known to what temperature the direct rays of the tropical sun can raise any object on which they fall. In India, on the ground, the uncovered thermometer will mark 160°, and perhaps 212° F.; and in this country, if the movement of air is stopped in a small space, the heat in the direct sun's rays can be raised to the same point. In experiments on frogs, when temperature much over the natural amount is applied to nerves, the electrical currents through them are lessened and at last stop. Analogous observations on man have shown that the same rule holds good; moreover, when the temperature of the blood of vertebrates exceeds 113° F., the myosin begins to coagulate. Perhaps this fact may explain why a very high temperature in any disease indicates extreme danger.

To what temperature is the skin of the head and neck raised in the tropics in the sun's rays? No sufficient experiments have been made, either on this point or on the heat in the interior of caps and hats with and without ventilation. Doubtless, without ventilation, the heat above the head in the interior of the cap is very great. It is quite possible, as usually assumed, that with bad head-dresses the heat of the skin, bones, and possibly even of the deep nerves and centres may be greater than is accordant with perfect preservation of the functions of the nerves, or of the necessary temperature of the blood, or with the proper fluidity of some of the albuminous bodies in the muscles or nerves. The difficulty of estimating the exact effect of the solar rays is not only caused by the absence of a sufficient number of experiments, but by the common presence of other conditions, such as an impure air, and heat of the body produced by exercise which is not attended by perspiration.

The effect of the direct rays on the skin is another matter requiring investigation. Does it aid or check perspiration? That the skin gets dry there is no doubt, but this may be merely from rapid evaporation. But if the nervous currents are interfered with, the vessels and the amount of secretion are sure to be affected, and on the whole it seems probable that a physiological effect adverse to perspiration is produced by the direct rays of the sun. If so, and if this is carried to a certain point, the heat of the body must rise, and, supposing the same conditions to continue (intense radiant heat and want of perspiration), may pass beyond the limit of the temperature of possible life (113° F.). In the Turkish bath it may sometimes be observed that, on entering the hottest chamber, the skin, which had previously been acting freely, becomes dry. A feeling of oppression accompanies this, but relief is experienced as soon as perspiration is re-established. This would seem to point more to an actual arrest of function than to a mere drying up of the secretion. The same thing in a modified degree may occur in a tropical climate, in which case the intensity of fever will depend upon the time that elapses before accommodation is reached.

The effect of intense radiant heat on the respiration and heart is another point of great moment which needs investigation. The pathological effect

produced by the too intense direct rays of the sun is seen in one or two forms of insolation, and in fatal cases apparently entails paralysis of the heart or respiration.

(*b*) *Heat in Shade.*—The effect of high air temperature on the native of a temperate climate passing into the tropics has not been very well determined, and some of the conclusions are drawn from experiments on animals exposed to an artificial temperature. In some observations made in 1897, by one of us (F.) during a voyage out to India, it was apparent that the *temperature* of the body rises as one passes into hotter regions. The amount of increase, as shown by thermometers in the rectum, was not great, but the average of seven soldiers who were under observation was 0·8° F. The controlling or dominant factor appeared to be atmospheric humidity rather than atmospheric heat. A similar rise was noted by Rattray,* his figures being from 0·2° to 1·2° F. There is no doubt but that tropical heat does raise the temperature of a new-comer, probably because the evaporation from the skin is not capable of counterbalancing the great additional external heat, but it is now known that in old residents the same fact does not hold good. The temperature of the body is the result of the opposing action of the two factors—1*st*, of development of heat from the chemical changes of the food, and by the conversion of mechanical energy into heat, or by direct absorption from without; and 2*nd*, and opposed to this, of evaporation from the surface of the body, which regulates internal heat. So accurately is this balance preserved, that the stability of the animal temperature in all countries has always been a subject of marvel. If anything, however, prevents this evaporation, radiation and the cooling effect of moving wind cannot cool the body sufficiently in the tropics. Then, no doubt, the temperature of the body rises, especially if in addition there is muscular exertion and production of heat from that cause. The extreme discomfort always attending abnormal heat of body then commences. In experiments in ovens, Blagden and Fordyce bore a temperature of 260° F. with a small rise of temperature (2½° F.), but the air was dry, and the heat of their bodies was reduced by perspiration; when the air in ovens is very moist and evaporation is hindered, the temperature of the body rises rapidly. Haldane's experiments, as to the precise point at which the effect of air temperature and humidity is reflected by a rise in body temperature, indicate that in a still atmosphere the point is a wet-bulb temperature of 88° F., and in moving air one of 93° F.

The *respirations* are lessened in number in animals subjected to heat. According to Vierordt, less carbon dioxide and presumably less water are eliminated. Rattray proved by a great number of observations that the number of respirations is lessened in persons passing from a cold to a hot climate. The amount of diminution varies; in some experiments the fall was from 16·5 respirations per minute in England, in winter, to 12·74 and 13·74 in the tropics. In another series of experiments the fall was from 17·3 respirations per minute to 16·1; the breathing is also shallower. Accompanying this lessened respiration rate is an increase in lung capacity, the gain amounting to about 12·25 per cent. It is doubtful, however, whether this is maintained. Certainly, for a time there is a decrease of quite 7·5 per cent. in the quantity of air respired daily in the tropics, and this decarbonising capability of the lungs is further curtailed by the fact that owing to its rarefaction, tropical or hot air contains less oxygen for a given volume than air of colder latitudes. The loss under this head is quite 3 per

* Rattray: "On the Effects of Change of Climate on the Human Economy," *Proc. Roy. Soc. London*, 1869–72, Nos. 122, 126, and 139.

cent. If we further take into consideration that there is diminished cardiac action equal to another 3 per cent., we get the value of the respiratory act in the tropics to be some 14 per cent. below that in a temperate climate. The consequent lessened loss of carbon by the lungs in the tropics is possibly largely compensated by increased functional activity of the liver and kidneys, which eliminate carbon in forms requiring less oxygen for their formation.

The *skin* acts much more than usual, and great local hyperæmia and swelling of the papillæ occur in new-comers, giving rise to the familiar eruption known as "prickly heat." In process of time, if exposed to great heat, the skin suffers apparently in its structure, becoming of a slight yellowish colour from, probably, pigmentary deposits in the deep layers of the cuticle.

The *urine* is lessened in quantity. The urea is lessened, as shown by experiments in hot seasons at home and during voyages. It is probable that this is simply from lessened food. The pigment has been supposed to be increased, but this is doubtful. The chloride of sodium is lessened; the amount of uric and phosphoric acids is uncertain.

The effect on the *nervous* system is generally considered as depressing and exhausting. But it is an undoubted fact that the greatest exertions both of mind and body have been made by Europeans in hot climates. Experience indicates that as much work can be got out of men in hot as in temperate climates. It is probable that the depressing effects of heat are most felt when it is combined with great humidity of the atmosphere, so that evaporation from the skin, and consequent lessening of bodily heat, are partly or totally arrested.

On the whole, even when sufficient perspiration keeps the body temperature within the limits of health, the effect of great heat in shade seems to be, as far as we can judge, a depressing influence lessening the nervous activity, the great functions of digestion, respiration, sanguification, and directly or indirectly the formation and destruction of tissues. Whether this is the heat alone, or heat and lessened oxygen, and great humidity, is not certain.

Rapid Changes of Temperature.—The exact physiological effects have not yet been traced out; and these sudden vicissitudes are often met by altered clothing, or other means of varying the temperature of the body. The greatest influence of rapid changes of temperature appears to occur when the state of the body in some way coincides with or favours their action. Thus, the sudden checking of the profuse perspiration by a cold wind produces catarrhs, inflammations, and neuralgia.

Effects of Cold.—The degree of cold which inhabitants of temperate climates can bear without ill effect is well shown in the experiences of Arctic voyagers. The actual effects of cold naturally vary in degree and kind. Much depends upon the degree of cold, the duration of the exposure, and the medium or manner of application; to these conditions may be added the extent of surface exposed and the general health or physiological condition of the person exposed. It is a matter of common knowledge that moderate cold, acting during a short time, or even very severe cold, during a still shorter time, when followed by the glow of reaction, exercises a tonic and stimulating influence.

In temporary exposure to cold, or even slight exposure, there is first the sensation of cold with pallor of the skin, shivering and tingling, followed by numbness: the pulse becomes slower, excretion of water by the lungs and skin diminishes, while the urine increases in quantity. If the exposure to

cold be prolonged, or the circulation and heat-producing powers cannot be maintained, the arterioles become contracted and no longer permit the passage of blood-corpuscles, and thus all physiological and chemical changes are arrested. The extremities become starved, and hence death of these parts takes place by frost-bite and gangrene. Prolonged exposure to extreme cold gives rise to an overpowering sense of languor, sensibility becomes lowered, the individual loses power of reaction and sinks to sleep or becomes delirious, death usually resulting from coma, though it may occur from syncope or asphyxia. Deprivation of food, partial or complete, materially adds to the hurtful influence of cold.

In the production of these effects it must be borne in mind that the actual temperature is not the only factor to be taken into consideration; dryness and stillness of the air permit a much lower temperature to be borne with comfort than when the air is damp or in motion. Even moderate wind renders a low temperature unbearable. It is the stillness and dryness of the air in Arctic regions, and at some health resorts at high altitudes, that render the extreme degrees of cold there prevalent not only tolerable but even beneficial. We have no evidence to say with certainty that any diseases are directly caused by cold. The specific fevers are generally less prevalent, and micro-organisms generally less active at low than at high or moderate temperatures. Catarrhal affections may be induced by sudden exposures to cold, or the so-called *chill*, but beyond this general statement we are not justified in going.

Influence of Atmospheric Humidity on Health.—According to their degrees of humidity climates are divided into moist and dry. As far as the body is concerned, the chief effect of moist air is exerted on the evaporation from the skin and lungs, and therefore the degree of dryness or moisture of an atmosphere should be expressed in terms of the relative (and not of the absolute) humidity, and should always be taken in connection with the temperature, movement, and density of the air, if this last varies much from that of sea-level. The evaporating power of an atmosphere which contains 75 per cent. of saturation is very different, according as the temperature of the air is 40° or 80° F. As the temperature rises, the evaporative power increases faster than the rise in the thermometer. There is a general opinion that an atmosphere which permits free without excessive evaporation is the best; but there are few precise experiments.

The most agreeable amount of humidity in temperate climates is when the relative humidity is between 70 and 80 per cent. In chronic lung diseases, however, a very moist air is generally most agreeable, and allays cough. The evaporation from the lungs produced by a warm dry atmosphere appears to irritate them. On the other hand, a still, cold atmosphere is dry, without much capacity for holding moisture; so that the bracing effects of the cold are felt, without the irritation produced by too rapid evaporation from the respiratory surface. This may be one cause (among others) of the benefit derived in winter from such places as Davos, &c.

From the experiments of Lehmann on pigeons and rabbits, it appears that more carbon dioxide is exhaled from the lungs in a very moist than in a dry atmosphere. The pathological effects of humidity are intimately connected with the temperature. Warmth and great humidity are borne on the whole more easily than cold and great humidity.

Influence of Air Movement on Health.—This is a very important climatic condition. The effect on the body is twofold. A cold wind abstracts heat, and in proportion to its velocity; a hot wind carries away little heat by direct abstraction, but if dry increases the evaporation.

and in that way may in part counteract its own heating power. Both, probably, act on the structure of the nerves of the skin and on the contractility of the cutaneous vessels, and may thus influence the rate of evaporation, and possibly affect also other organs.

The amount of the cooling effect of moving bodies of air is not easy to determine, as it depends on three factors—viz., the velocity of movement, the temperature, and the humidity of the air. The effect of movement is very great. In a calm atmosphere an extremely warm temperature is borne without difficulty. In the Arctic expeditions calm air, many degrees below zero of Fahrenheit, caused no discomfort. But any movement of such cold air at once chills the frame. It has been asserted that some of the hot and very dry desert winds will, in spite of their warmth, chill the body; and if so, it can scarcely be from any other reason than the enormous evaporation they cause from the skin. It is very desirable, however, that this observation should be repeated, with careful thermometrical observations both on the body in the usual way and on the surface of the skin.

As bearing upon their influence on health, we may summarise by saying, that warm and moist winds, such as the south-west wind in these islands, are mild and relaxing; dry, cool winds, such as our east wind, are bracing; but this wind, on account of its penetrating character, is often dangerous to those having any weakness of the lungs, and is also hurtful to those liable to rheumatism or liver congestion.

Influence of Atmospheric Pressure on Health.—When the difference of pressure between two places is considerable, a marked effect is produced, so much so that the influence of mountain localities plays a very important part in modern therapeutics. From the hygienic point of view, this subject involves the consideration of (1) the effects of lessened pressure, and (2) the effects of increased pressure.

Effects of Lessened Pressure.—In ascending mountains there is rarefaction—*i.e.*, lessened pressure of air; on an average an ascent of 900 feet takes off half a pound; but this varies with height; about one-eighth of the atmospheric pressure is lost at 2500 feet, a sixth at 5000 feet, a quarter at 7500 feet, and at 16,000 feet about one-half. There are also lowered temperature and lessened moisture above 4000 feet, greater movement of the air, increased amount of light, greater sun radiation if clouds are absent; the air is freer from germs; owing to the rarefaction of the air and lessened watery vapour, there is greater diathermancy of the air; the soil is rapidly heated, but radiates quickly, as the heat is not so much held back by vapour in the air, hence there is very great cooling of the ground and the air close to it at night.

The physiological effects of lessened pressure begin to be perceptible at 6000 or 7000 feet of altitude; they are—quickened pulse; quickened respiration with lessened spirometric capacity, increased evaporation from skin and lungs; lessened urinary water. At great heights there is increased pressure of the gases in the body against the containing parts; swelling of superficial vessels, and occasionally bleeding from the nose or lungs. A sensation of weight is felt in the limbs from the lessened pressure on the joints. At altitudes under 6000 or 7000 feet the effect of mountain air is to cause a very marked improvement in digestion, sanguification, and in nervous and muscular vigour. It is inferred that tissue change is accelerated, but nothing definite is known.

In the ascent of the balloon "Zenith," two occupants died on attaining a height of 8600 metres, while a third became unconscious. This altitude is equivalent to a pressure of 260 mm. of mercury or, as regards oxygen, equal

to 7 per cent. of an atmosphere. In a pneumatic chamber, in which the pressure had fallen to 192 mm. of mercury, Mosso became too apathetic to pick up a pencil which he had dropped. The air at this stage, enriched by oxygen sent into the chamber, yielded 8·14 per cent. of an atmosphere of oxygen. Under ordinary atmospheric pressure, hyperpnœa is produced when the oxygen falls to 13 per cent., and is excessive at 6 per cent. A man breathing air poor in oxygen will usually become unconscious when the oxygen has fallen to 8 or 6 per cent. Accommodation to high altitudes is probably associated with changes in the blood, the circulation and respiration. The highest dwelling-place, continuously occupied, is the observatory El Misti, in the Andes, at 5880 metres.

As a curative agent, mountain air ranks very high in all anæmic affections from whatever cause; and it would appear, from Hermann Weber's observations, that the existence of valvular heart disease is, if proper rules are observed, no contra-indication against the lower elevations (2000 to 3000 feet). Neuralgia, gout, and rheumatism are all benefited by high Alpine positions. Scrofula and consumption have been long known to be rare among the dwellers on high lands, and the curative effect of such places on these diseases is also marked; but it is possible that the open-air life which is led has an influence, as it is now known that great elevation is not necessary for the cure of phthisis. Weber and others have shown how in the true Alpine region, in Dauphiné, in Peru and Mexico, and in Germany, phthisis is decidedly averted or prevented by high altitudes. The more recent experience of Davos Platz is certainly confirmatory of this.

Although on the Alps phthisis is arrested in strangers, in many places the Swiss women on the lower heights suffer greatly from it; the cause is a social one: the women employed in making embroidery congregate all day in small, ill-ventilated low rooms, where they are often obliged to be in a constrained position; their food is poor in quality. Scrofula is very common. The men, who live an open-air life, are exempt; therefore, in the very place where strangers are getting well of phthisis the natives die from it—another instance that we must look to local conditions and social habits for the great cause of phthisis; that is, that in most cases this disease is due to the breathing of impure air, containing the infective bacillus. It would seem that it is not elevation and rarefaction of air, but simply plenty of pure air and exercise which are the great agents in the cure of phthisis.

The diseases for which mountain air is least useful are—rheumatism, at the lower elevations where the air is moist (above this rheumatism is improved), and chronic inflammatory affections of the bronchial tubes for pleura, and neuralgia. The "mountain asthma" appears, however, from Weber's observations, to be no specific disease, but to be common pulmonary emphysema following chronic bronchitis.

Effects of Increased Pressure.—The effects of increased pressure have been noticed in persons working in diving-bells, caissons, &c., and in those submitted to treatment by compressed air, especially at Lyons and at Reichenhall. When the pressure is increased to from $1\frac{1}{4}$ to 2 atmospheres, the pulse becomes slower, though this varies in individual cases; the mean lessening is ten beats per minute; the respirations are slightly lessened (1 per minute); evaporation from the skin and lungs is said to be lessened (?); there is some recession of blood from the peripheral parts; there is a little ringing and sometimes pain in the ears; hearing is more acute; the urine is increased in quantity; appetite is increased; it is said men will work more vigorously. When the pressure is much greater, the effects are some-

times very marked; great lowering of the pulse, heaviness, headache, and sometimes deafness. It is said that more oxygen is absorbed, and that the venous blood is as red as the arterial; the skin also sometimes acts more, and there may even be sweating. The main effect is to lessen the quantity of blood in the veins and auricles, and to increase it in the arteries and ventricles; the filling of the ventricle during the relaxation takes place more slowly. The diastolic interval is lengthened, and the pulse is therefore slower.

In pneumatic chambers and tubes used for pier driving and laying the foundations of bridges the pressure in the air chambers is usually of from 3 to 4 atmospheres, and if due precautions are taken to neither increase nor lower the pressure too rapidly, no symptoms or inconvenience are experienced by workmen when employed in them for hours together. What accidents and ill effects have occurred are chiefly in the form of prickings, muscular pains, nose-bleedings, and paralysis, and these have occurred commonly after leaving the high-pressure chambers or tubes, and when the reduction of pressure has been too rapid. Very few unfavourable effects appear to occur under the actual high pressure. The great danger in all these cases appears to be in the too sudden reduction of pressure. If time be given, the body seems to be quite able to accommodate itself to the extreme variations of pressure. Recent experiments by Hill and Macleod in England, and of Heller, Mager and von Schrötter in Austria confirm this view.* When unfavourable effects follow exposure to high pressure of air and too rapid decompression, the cause is generally believed to be due to the escape of bubbles of free nitrogen into the blood, the gas having been dissolved previously therein; this view has been challenged by Macnaughton † who attributes the symptoms which supervene, upon being released from confinement under high atmospheric pressure, to frictional electricity generated by the passage of the air under pressure along lengths of metal tubing. As a result of this the atmosphere of caissons or other confined spaces in which the air is forced in and maintained under pressure, is highly charged with electricity. Although the amount be insufficient to produce a conscious effect upon the exterior, the nerve-cells are thrown into a state of excessive activity manifesting itself in discharges of a purposeless motor and sensory nature. When decompression takes place, there follows a rapid decomposition of electricity, and the fall of electric potential in the body causes the symptoms experienced. This view is not generally accepted, but it has been advanced; in the same way, it has often been asserted that quantities of carbon dioxide, innocuous at ordinary pressures, become toxic in compressed air; there is little or no evidence in support of this idea. The general facts suggest the following conclusions: increased air pressures up to seven atmospheres do not produce any unfavourable symptoms, provided the rate of decompression be sufficiently slow, that is, at the rate of twenty minutes for each atmosphere of positive pressure.

As a curative agent in phthisis, the use of compressed air has so far been unfavourable, but is of more benefit in asthmatic cases. In the "compressed air bath" at the Brompton Hospital the pressure rarely exceeds an addition of 10 lb. to the square inch, or $\frac{2}{3}$ of an atmosphere. Half an hour is given to reach this pressure, it is maintained for an hour, and half an hour is occupied in reducing it to the natural pressure; thus all danger of sudden change is taken away.

* Greenwood: "The Influence of Increased Barometric Pressure on Man." *Brit. Med. Journal*, 1906, vol. i. p. 912.

† Macnaughton: "Frictional Electricity: a Factor in Caisson Disease," *Lancet*, 1906, vol. ii. p. 435.

Acclimatisation.—The doctrine of acclimatisation has been much debated, but probably we do not know sufficiently the physiological conditions of the body under different circumstances. In the case of Europeans living until puberty in a temperate region, near the sea-level, and in a moist climate like England, and then going to the tropics, the question of acclimatisation would be put in this form—Does the body accommodate itself to greater heat, to lessened humidity in some cases, or greater in others, and to varying altitudes ?

There can be little doubt that the body does accommodate itself within certain limits to greater heat, as we have seen that the lungs act less, the skin more, and that the circulation lessens when Englishmen pass into the tropics. There is so far an accommodation or alteration impressed on the functions of the body by unwonted heat. And we may believe that this effect is permanent—*i.e.*, that the lungs continue to act less and the skin more as long as the Europeans remain in the tropics. Doubtless, if the race were perpetuated in the tropics, succeeding generations would show fixed alterations in these organs.

We may conclude that the converse holds true, and that the cold of temperate regions will influence natives of the tropics in an opposite way, and this seems to be rendered likely by the way in which lung affections arise in many of them.

We may admit there is an acclimatisation in this sense, but in no other. The process is one of adaptation rather than acclimatisation. The usual belief that the constitution acquires in some way a power of resisting unhealthy influences—that is, a power of not being any longer susceptible to them—is not supported by any good evidence. The lungs in Europeans will not regain their weight and amount of action in the tropics ; a change to a cold climate only will cause this ; the skin retains its increased function until the cause producing it is removed.

From the results of a long extended inquiry into the effects of climate on different races of people, Stokvis * concludes " that the power of resistance of the healthy adult European living in the tropics quite equals, and in some measure is even superior to, the vital power of the native races." On the other hand, there are certain peculiarities of the race which have been gradually acquired by inheritance from generation to generation, and that the longer the European resides in the tropics the more likely is he to lose his superior resisting powers ; and it is possible that the European Creole is both bodily and mentally inferior to the European.

Classification of Climates.—The simplest plan of classifying climates is based upon geographical limits, and largely according to latitude. This at best is imperfect unless allowance be made for the influence of warm or cold sea-currents, large ocean areas, and the nearness or distance of mountain ranges. These latter in particular greatly affect rainfall and exposure to winds. Allowing for these modifying influences, and based upon the principle or limits of latitude, a commonly accepted classification of climates is as follows :—

Warm Climates.—These include the greater part of Africa and its islands ; Southern Asia, embracing India and China ; Polynesia, including all Australia except Victoria ; North America south of California ; and South America north of Uruguay, with the West Indies. These climates are marked by high temperature, heavy rainfall, and more or less well-defined dry and wet seasons. Such climates are usually met with in places lying between the equator and 35° of latitude north or south of it. They can be subdivided

* Stokvis : Address on " Colonial Pathology," *Trans. Internat. Med. Congress, Berlin,* 1890.

into equatorial, tropical, and sub-tropical groups. In the equatorial the mean annual temperature is from 80° F. to 84° F., the minimum being 54° F. and the maximum 118° F. The mean temperature decreases slowly as we recede from the equator. The difference of temperature during the day is slight, but there is a marked fall at night from radiation. The rainfall is rarely less than 40 inches annually, and it is this which tempers and reduces the otherwise extreme heat.

Though possibly all the diseases usually attributed to the influence of warm climates are not rightly so, still these climates are peculiarly apt to be associated with such affections as heat-stroke, yellow fever, cholera, dengue, liver abscess, dysentery, small-pox, and various forms of malarial fever, while scarlet fever and measles are comparatively rare.

Temperate Climates.—These have a mean temperature of 60° F., often with great extremes; four well-defined seasons, usually most rainy during autumn and winter; and the geographical limits of from 35° to 50° of latitude. The temperate climates are inhabited by the most vigorous races of the world, and would seem to have been in all ages specially favourable to the physical and intellectual growth of the human race. The most prevalent diseases are for the most part the ordinary diseases of Europe and America, especially rheumatism, acute and chronic pneumonia, various affections of the air-passages, and the large group of exanthemata. Pulmonary consumption is common, but cannot be said to be the special production of these climates.

Cold Climates.—These belong to regions situated between 50° of latitude and the poles. In them the summer is short, often lasting but a few weeks, while the winter is long. Snow is extensive, but of rain there is little or none. The temperature falls rapidly between latitudes 55° and 75°, and the fall amounts to 22° F. to 27° F., the coldest region being not at the pole, but about 10° from it north of Behring Straits, the mean temperature there ranging between 17° F. and 19° F.

Scurvy and scrofula are the principal affections which can be directly attributed to these climates,—the former arising from a deficient supply of fruit and vegetables, and the latter from the overcrowding and general poorness of living which prevails. Ophthalmia and amaurosis are also reported to be present, from the reflection of light from the snow in the polar regions. The extreme and dry cold, which is the feature of these climates, has a bracing effect on the system, improves the appetite, promotes the performance of muscular work, and, as it is fatal to all micro-organisms, is a good antiseptic.

Mountain Climates.—These are peculiar, being marked by extremes of temperature, great clearness and rarefaction of the atmosphere, and lessened barometric pressure. Among the more important of these climates are (1) the Alpine, where the winter is very cold, dry, and calm, but the sun's rays are most powerful; (2) the Rocky Mountains of North America, where the climate resembles that of the Alpine resorts, although warmer, drier, less snow, but more dust; (3) the sanitaria of the Andes, with a climate generally dry, warm, and bracing, except at La Pas, where the winter is cold; (4) Himalayan stations, where the climate is cool, but subject to considerable extremes, and damp owing to the excessive rainfall; (5) the South African Highlands of Cape Colony, Orange River Colony, and the Transvaal, where the climate is warm, with seldom any extreme of cold except during the rainy season and a few days of winter.

Mountain climates are peculiarly favourable to those having imperfect chest development, with hereditary or other tendencies to consumption;

but are unsuitable for those troubled with chronic bronchitis, or acute diseases of the lungs, kidneys, liver, or brain. The peculiar effects of mountain climates appear to be due to the increased aeration of the blood which takes place during the act of breathing mountain air, and, as a result of this, these climates are best suited for those capable of taking abundant exercise, and distinctly hurtful to the aged and very feeble.

Marine climates are those prevailing upon islands, capes, and sea coasts, in which the temperature is remarkably equable, rarely reaching extremes, and in which, owing to the increased moisture and rainfall, a certain softness of atmosphere is experienced. The climates of Great Britain, Norway, and Iceland may be taken as types of these so-called marine climates.

The principal diseases which appear to be in any way peculiar to marine climates are rheumatism, and the various affections of the lungs and air-passages, the greater part of which may be due to the dampness and constant weather changes which are so characteristic of these climates.

METEOROLOGY

Meteorology is the science of weather; while the word weather denotes the general condition of the atmosphere at any particular time, and especially of that portion of the atmosphere near the surface of the earth. These definitions suggest that weather is a general result produced by the combined action of several different elements, each consisting of a special set of phenomena in the physics of the atmosphere, such as those depending on its warmth, motion, dryness, humidity, transparency, and the like; while the leading principles of modern scientific meteorology are first, the making of accurate and systematic observations of these phenomena, and secondly, their practical interpretation. The making of meteorological observations presents for the most part no great difficulty, the essential qualification being "a capacity for doing a small piece of routine work at stated times, without losing interest in it, and so becoming careless." To be of any value the observations made at different places must be comparable; the instruments used must be similar in form, exposed in a similar way, and the errors peculiar to them and to the observer must be known.

TEMPERATURE, HOW OBSERVED AND CALCULATED.

Thermometers.—The principle of these instruments is that they measure temperature by the expansion of bodies. The first thermometer is supposed to have been invented by Sanctorio, of Padua, in 1590; but the history of the instrument practically dates from 1714, when Fahrenheit of Dantzic constructed the thermometer known by his name.

Liquids are the bodies best suited for the purpose of indicating, by their expansion or contraction, the intensity of heat, in the construction of thermometers; the expansion of gases being too great, and that of solids too small. Of liquids, mercury and alcohol are practically the only ones used; the former because of its equal expansion at different temperatures, its low freezing-point ($-37^\circ{\cdot}9$ F.), its high boiling-point ($675^\circ{\cdot}1$ F.), its high conductivity of heat, and its low specific heat; alcohol is used because at atmospheric pressure it does not solidify at the greatest known cold. For these reasons,

mercury is used for recording high degrees of heat, and alcohol for low temperatures.

A thermometer consists of a capillary glass tube of uniform bore, closed at one end, and blown out at the other into a bulb or reservoir which is filled with mercury or spirit. Both the bulb and a part of the stem are filled with mercury or spirit, and the expansion or contraction is measured by a scale graduated either on the stem itself, or on a frame to which it is attached. The construction of a thermometer involves the following operations :—*calibration or division of the tube into parts of equal capacity, filling the thermometer, and the graduation.* In order to provide the thermometer with a scale to which variations of temperature can be referred, two points must be fixed which represent identical temperatures. " Experiment has shown that ice constantly melts at the same temperature, whatever be the degree of heat, and that distilled water under the same pressure and in a vessel of the same kind always boils at the same temperature. Consequently, for the first fixed point, or zero, the temperature of melting ice has been taken ; and for the second point, the temperature of boiling water in a metal vessel under the normal atmospheric pressure of 760 millimetres."

On the Continent, the space between zero and the boiling-point is divided into 100 parts, and this division is called the Centigrade or Celsius scale. Another scale, introduced by Réaumur, has the same fixed points as in the Centigrade, but the interval between them is divided into 80 instead of 100 parts.

In England and America, for general use, the thermometric scale invented by Fahrenheit is still employed. In this scale the higher fixed point is, like that in the Centigrade and Réaumur scales, that of boiling water ; but the lower fixed point or zero is not the temperature of melting ice, but that obtained by mixing equal parts of snow and sal ammoniac, and the interval between the two is divided into 212 parts or degrees. The zero temperature on this scale is lower than that of melting ice, with the result that when a Fahrenheit scale thermometer is placed in melting ice, it stands at 32 degrees, and, therefore, 100 degrees on the Centigrade scale and 80 on the Réaumur equal 212 less 32, or 180 degrees on the Fahrenheit, or 1 degree Fahrenheit equals $\frac{5}{9}$ of a degree Centigrade. and $\frac{4}{9}$ of a degree Réaumur. For the conversion of any given number of degrees Fahrenheit into Centigrade or Réaumur degrees, the number 32 must be first subtracted in order that the degrees may count for the same part of the scale, and the result then multiplied by the relative value of the two degrees. Conversely, Centigrade and Réaumur degrees may be converted into Fahrenheit by adding 32 after multiplying by the ratio value. To convert Centigrade degrees into those of Réaumur it is necessary to multiply them by $\frac{4}{5}$; similarly, Réaumur degrees are transferred into Centigrade ones by multiplying them by $\frac{5}{4}$.

In both the Réaumur and Centigrade scales all temperatures below the freezing-point have a " minus " sign prefixed to them. In the case of the Fahrenheit scale the zero is 32 degrees below the freezing-point, so that the " minus " sign is seldom used for temperatures occurring in the United Kingdom. The Fahrenheit and Celsius scales agree at $-40°$.

It has been found that in the course of time the zero of a thermometer tends to rise, so that when it is immersed in melting ice the mercury no longer sinks to zero. This displacement of the zero is generally attributed to a diminution of the volume of the bulb and also of the stem, occasioned by the pressure of the atmosphere. When very accurate thermometers are required it is usual to fill them two or three years before they are graduated.

A good mercury thermometer should answer to the following tests.

When completely immersed in melting ice, the top of the mercury should exactly indicate zero or 32°, according as to whether the scale be Centigrade and Réaumur or Fahrenheit ; and when suspended in the steam of water boiling in a metal vessel with the barometer at 29.92 inches, the mercury should be stationary at either 100° or 212° according to the kind of scale. The value of the degrees should be uniform, as shown by a detached piece of mercury occupying an equal number of degrees in all parts of the tube.

The thermometers used in meteorological observatories are of various kinds :—standard thermometers, ordinary thermometers, registering thermometers, sometimes called maximum and minimum thermometers, self-recording thermometers, and radiation thermometers.

A *Standard thermometer* is employed for testing the accuracy of the instruments used for ordinary observations. Standard thermometers are usually mercurial, because, between the two fixed points on the scale, the expansion of mercury is perfectly uniform. Its scale must be cut on the stem, and should range from far below zero to the boiling-point of water. The scale should not be marked for several years after the tube has been filled, in order to guard against the defect known as the displacement of zero, arising from the gradual contraction of the bulb, which results from the slowness with which fused glass returns to its original density. As the bulb contracts, it holds less mercury, which is forced into the tube to a higher level than the temperature warrants, whereby the instrument tends to read too high.

Ordinary thermometers need no special remarks beyond that they should be constructed of mercury, and have a certificate of verification from some recognised scientific institution. In order to guard against the defect produced by the "displacement of zero," it is advisable, at least once a year, to determine the freezing-point of water on the thermometers by immersing them in melted snow or ice.

Registering thermometers are instruments provided with an arrangement which indicates the highest or lowest temperature to which they have been exposed.

Maximum thermometers are of two kinds, Phillip's and Negretti's. Both these instruments have mercurial columns, a detached portion of which serves as an index for the highest temperature reached. In Phillip's the detached portion of the mercurial column is separated from the rest by a bubble of air. In Negretti's the detachment is made by means of a slight contraction of the tube, which, while allowing the expanding mercury to pass when the temperature is rising, is sufficient to overcome the natural cohesion of the metal when contracting, to prevent it drawing it back on cooling. Both these instruments are placed horizontally, and both can be reset by lowering the bulb, and then either gently tapping or swinging the thermometer.

Minimum thermometers are instruments in which a small metallic index is immersed in the spirit with which the bulb and part of the stem are filled. When the temperature falls, and the alcohol contracts, the capillary attraction of the liquid draws the index back with it towards the bulb ; but when the temperature rises again, the alcohol passes the index, and leaves the extremity of it farthest from the bulb at the lowest temperature reached. The instrument, after having been read, is readily set by partially inverting it and letting the index fall to the top of the spirit column ; it is then hung up in a horizontal position. Occasionally air bubbles appear in the alcohol and fix the index, while at other times some of the alcohol volatilises and condenses at the top of the tube. Both these faults can be easily cured by holding the thermometer bulb downwards and swinging it rapidly round ;

this will usually cause the air bubbles to disperse, and displace any condensed alcohol from the top of the tube. If, by chance, as the result of this procedure the index be thrown into the bulb, a little tapping and patience will bring it out again.

Previous to the invention of these maximum and minimum thermometers, a registering instrument known as Six's thermometer (Fig. 170), from the name of its inventor, was much used, and is so now. The tube of the instrument is long and U-shaped. One limb constitutes the cold tube, and has at its extremity a bulb, while the other limb is the heat tube, having at its top or end a small chamber in which is confined some air. The middle portion of the tube contains mercury extending round the bend and part of the way up each limb. The bulb and both tubes or limbs above the mercury contain alcohol. Inside the alcohol are two steel indices, one being in the cold and the other in the heat tube. These are readily set, or caused to rest gently upon either column of mercury by moving them by means of a magnet. This being done, if the temperature rises, the alcohol in the bulb will expand and push down the mercury in the cold leg, but raise that in the heat leg, and by so doing drive up the index in it until the temperature ceases to rise, when the point of maximum heat will be indicated by the lower end of that index. On a fall of temperature precisely the reverse will happen, for then the spirit within the bulb will contract, and the pressure in the air chamber at the top of the heat leg will force the mercury down in it, but up in the cold limb, while the cold index will continue to go up so long as the temperature continues to fall. Of course the scales read downwards on the cold leg and upwards in the heat one, and in each the lower end of the index shows respectively the lowest and highest temperature reached since the instrument was last set. The presence of the air chamber makes a Six's thermometer unsuited for travelling, and necessitates the vertical position. The instrument is further liable to error, owing to the fact that sometimes alcohol will ooze round by the side of the mercury, and so pass from the cold to the heat leg. As the scales run in opposite directions, it is obvious that if this defect occurs, it gives rise to a large error in the reading of the temperature. No one but a skilled optician can rectify this evil.

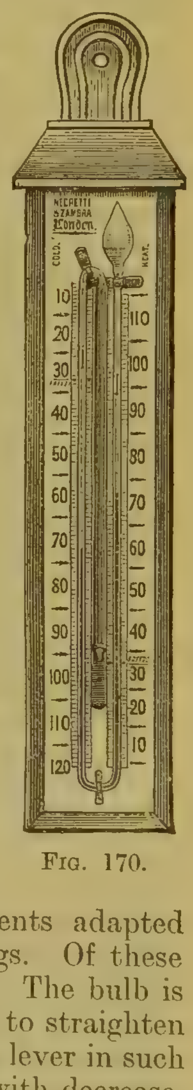


FIG. 170.

Self-recording thermometers, or thermographs, are instruments adapted with an arrangement by which they record their own readings. Of these instruments those of Cripp or Richard are familiar examples. The bulb is a large curved flattened tube, filled with a liquid which tends to straighten with an increase of heat, and this, being connected with a long lever in such a manner as to rise with increase of temperature and to fall with decrease, marks a tracing line upon a revolving cylinder. This cylinder depends upon a clockwork arrangement, and can be wound up, started and left untouched for given periods of time, at the end of which records of temperature will be found for every instant during the period. As the curvature of the tube and the spring mechanism are apt to alter, these instruments need to be corrected and compared periodically with an accurate mercurial thermometer.

Radiation thermometers are commonly employed to afford a measure of the intensity of the heat radiations received from the sun, or given off by the surface of the earth.

Some idea of the intensity of the sun's heat is obtained by means of what

are called *solar radiation thermometers* or maximum thermometers placed direct in the sun's rays. In order to avoid loss of heat by reflection from the bright glass surface of the bulb, this and one inch of the stem is coated with lamp-black, and this again, to protect it from being washed off by rain, is placed in a glass case out of which air has been pumped to make it a vacuum. Unfortunately, the presence of the outer glass covering largely interferes with the cooling influence of wind, which materially affects the distribution of heat by the sun in nature. Notwithstanding this theoretical defect, the blackened bulb maximum thermometer *in vacuo* is the best instrument we have for measuring the amount of heat given out or radiated by the sun. The instrument is exposed freely to the sun and air by fixing it horizontally 4 feet above the ground, well away from trees or walls, and with its bulb, in this country, pointing south-east. The heat recorded by such an instrument will be the temperature at which the equilibrium or balance is established between the heat produced by the direct rays of the sun on the bulb, and the cooling caused by radiation or loss of heat from the bulb to the glass jacket or covering; this latter, of course, will have practically the same temperature as that of the air. It follows, therefore, that the excess of the temperature of the black bulb over that of the outer air, as registered by a maximum thermometer in the shade, will be an approximate measure of the power of the actual sun's rays, or in other words, the power of the sun's radiation of heat. Thus, suppose the black bulb thermometer shows a reading of 116°, and the shade or air maximum be 76°. The difference between them of 40° will be the approximate measure of the sun's intensity. As an alternative method, it has been suggested to expose alongside of the black bulb *in vacuo* a similar thermometer also *in vacuo*, only with its bulb bright, and to register the difference between the readings of the two instruments as the amount of solar radiation. It has been objected, with some reason, to both these methods that the indications of the black bulb or sun maximum thermometer are not of much value, because, in the first place, the sun's rays do not necessarily have their greatest power at the hour of maximum air temperature, but much earlier, and that to obtain reliable results we should therefore subtract from the black bulb reading, not the maximum, but the actual air temperature at the moment the black bulb reaches its highest point. What is really wanted is a measure of the total heat received from the sun, not a record of its maximum intensity at any instant.

Not only is there a constant gain of heat by the earth from the sun, but there is also a more or less constant loss of heat from the earth and from all objects on it. This loss of heat is spoken of as *terrestrial radiation*, and is very much greater when the sky is clear than when overcast with clouds. The amount of this loss of heat by radiation is determined by placing a minimum thermometer, as already described, on short supports some 4 inches off the ground, preferably on a plot of grass. Should the ground be covered with snow, the instrument should be laid upon the surface of the snow. Where a grass plot is not available, the thermometer should be placed on a large black board laid upon the ground. The difference or defect of this minimum temperature below that of the air minimum in the shade is taken as the amount of terrestrial radiation. The bulb of minimum thermometers used for this observation is often modified so as to present the greatest amount of surface relatively to its contents, either by making it in the form of a hollow cylinder, or by arranging it in the form of a fork, or by drawing it out and bending it back upon itself.

Thermometer Exposure.—The method of exposing radiation thermometers has been definitely stated, but the proper exposure of other or

shade thermometers so that they may indicate the true temperature of the air is a matter of some difficulty. Two conditions are required : (1) a constant circulation must be kept up round the thermometer bulbs, and in its passage to the instruments the air must not have its temperature changed by passing over hot or cold surfaces ; (2) the thermometer bulbs must be protected not only from the direct rays of the sun, but from radiations of all kinds from surrounding objects. These conditions are probably most nearly realised by the sling thermometer, which is attached to a cord some 2 feet in length and swung round like a sling in the shade. Obvious objections exist to observations of this kind, and various kinds of thermometer shelter have been devised. Perhaps the best is that used in this country and called after its inventor the "Stevenson" screen. It consists merely of a hut or box made of stout boards, with a ridge roof and louvred sides, open below, and standing some 4 feet off the grass on four legs. It should be placed where it will be freely exposed to the movements of the air, and at least 20 feet away from any house or building.

Reading of Thermometers.—All good thermometers can be read by the eye to tenths of a degree. The maximum and minimum thermometers are read once a day, usually at 9 A.M. ; the former marks the highest point reached on the *previous* afternoon, and must be so entered on the return ; the latter. the lowest point reached on the *same* morning. For the army returns the ordinary thermometer is read twice a day, at 9 A.M. and 3 P.M.

Range of Temperature.—The maximum and minimum in shade give most important climatic indications ; the difference between them on the same day constitutes the range of the diurnal fluctuation. The range is expressed in several ways.

The extreme daily range in the month or year is the greatest difference between the maximum and minimum thermometer on any one day.

The extreme monthly or annual range is the difference between the greatest and least height in the month or year.

The mean monthly range is the daily ranges added and divided by the number of days in a month (or the difference between the mean of all the maxima and the mean of all the minima).

The yearly mean range is the monthly ranges added and divided by 12.

Mean Temperature.—The mean temperature of the day is obtained in the following ways :—

(*a*) At Greenwich and other observatories, where by means of photography the height of the thermometer at every moment of the day is registered, the mean of the hourly readings is taken. This has been found to accord with the absolute mean (found by taking the mean of the whole curve) to within $\frac{1}{10}$th of a degree. It may also be recorded by means of a self-registering instrument.

(*b*) Approximately in several ways. Taking the mean of the shade maximum and minimum of the same day. In this country, during the cold months (December and January), the result is very close to the truth ; but as the temperature increases a greater and greater error is produced, until in July the mean monthly error is + 1°·9 F., and on some hot days is much greater. In the tropics, the mean of the maximum and minimum must give a result still further from the truth.

The nearest approach to the mean temperature of the day by a single observation is given at from 8 to 9 P.M. ; the next is in the morning—about 8 o'clock in July and 10 in December and January. The mean monthly temperature is the mean of the daily means : the mean annual temperature is the mean of the monthly means.

The nearest approach to the mean annual temperature is given by the mean of the month of October. Observations made from a week before to a week after April 24, and again in the corresponding weeks of October, give a certain approximation to the yearly mean temperature.

The changes in temperature of any place, during the day or year, are either *periodic* or *non-periodic*. The former are dependent on day and night, and on the seasons, *i.e.*, on the position of the place with respect to the sun. The periodic changes are sometimes termed fluctuations, and the differences between day and night temperatures, or the temperatures of the hottest and coldest months, are often called the amplitudes of the daily or yearly fluctuations.

Daily Periodic Changes.—On land, the temperature of the air is usually at its lowest about 3 o'clock A.M., or just before sunrise, and at its maximum about 2 o'clock P.M.; it then falls steadily to 3 o'clock A.M. At sea, the maximum is nearly an hour later.

The amount of diurnal periodic change is greater on land than on water; in the interior of continents than by the seaside; in elevated districts than at sea-level. As far as land is concerned, it is least on the sea-coast of tropical islands.

In Sind and Baluchistan, and throughout the dry tract to the west of the Jumna, the daily range of the thermometer is greatest in October and November, when the difference between sunrise and afternoon averages not much less than 30° F., and sometimes 40° F. The same occurs in the northern districts of Bombay in the earlier months of the year, when land winds, from between west and north-west, blow most steadily. In the North-West Provinces of India it averages 28° to 32° F., both in March and April. These variations take place daily, and with much regularity.

Yearly Periodic Changes.—In the northern hemisphere the coldest month is usually January; in some parts of Canada it is February. On the sea the coldest month is commonly March. The hottest month is in most places July, in some few August; on the sea it is nearly always August. The coldest days in this country are about the 21st January; the hottest about the 21st July.

It is thus seen that both for the diurnal and annual alterations of heat the greatest heat is not simultaneous with, but is after, the culmination of the sun; this is owing to the slow absorption of heat by the earth.

The amplitude of the yearly fluctuation is greater on land than sea, and is augmented by land, so that it reaches its highest point in the interior of great extra-tropical continents. Usually, it is very small in the tropical lands at sea-level, while it is immense on continents near the poles. All fluctuations depend to a large extent upon the distance from the sea, although local causes may have some influence, such as the vicinity of high lands.

The difference between the highest and lowest readings recorded at Leh, which is the most northerly and driest station where observations are recorded in India, averages 94° F., and has been as much as 103° F. On the plains of the Punjab it varies from 80° F. (at Mooltan) to 86° F. at Peshawar, and sometimes reaches 92° F. At the hill stations it is much less.

Temperature of the Air of any place.—This depends on the following conditions, namely, latitude, altitude, relative amount of land and water, the other chief influencing circumstances of local importance being *aspect* and the *nature of the soil*. To these may be added *forests*, which, in hot climates especially, greatly moderate the heat, by shielding the soil from the sun's rays, and by evaporation from the leaves.

Distribution of Temperature.—The manner in which heat is distributed over the globe is shown by maps on which are drawn *isothermal* lines, or lines connecting places that have the same mean temperatures: these mean temperatures may be either for the year or for several months. The region of highest mean monthly temperature, shown by an isothermal line of 90° F. for July, encloses a tract extending from about 8° W. long. in north Central Africa, to about 72° E. long. in the Punjab, forming a belt of about 18° in width; its southern limit in Africa being about 9° N. lat., its northern limit reaches nearly 35° N. lat.

The hottest places on the earth are—in the eastern hemisphere, near the Red Sea at Massowah, and at Khartoum (15° N. lat.), and on the Nile in Lower Nubia; annual temperature = 90°·5 F.: in the western hemisphere, on the Continent, near the West Indies, the mean annual temperature is 81°·5 F. These are sometimes called the climatic poles of heat. The highest readings of a well-shaded verified thermometer in India have been 123°·1 F. at Pachpadra, in Rajputana, and 122°·2 F. at Jacobabad, both on May 25, 1886. The poles of cold are in Siberia and near Melville Island. The lowest readings recorded have been – 69° F. by Kane at Rensselaer harbour in Greenland, and – 81° F. by Govochow at Wenchojausk in Siberia.

SUNSHINE.

The duration of the sunshine is a very important factor in all climates, and the extent of this duration is recorded by a variety of instruments. They consist mainly of a glass sphere, so mounted that where the sun shines its rays are focussed as by a lens upon a strip of cardboard or on sensitised paper, with the result that a permanent record or track is left for such periods of time as the sun shines. The more reliable instruments of the kind are McLeod's and the Campbell-Stokes. In the former, there is a cylindrical metallic camera, opposite to the lens of which is a thin glass sphere silvered inside. The support of the instrument is constructed by the maker to suit the latitude, and the observer has merely to place it in the meridian. Jordan's instrument is, strictly speaking, a recorder of sunlight rather than of sunshine.

WIND.

The facts to be observed relating to winds are practically limited to those connected with direction, force or pressure, and velocity.

Direction.—As a rule, there is comparatively little trouble in obtaining records as to direction, as if no vane is convenient, the smoke from a chimney will readily give the information, provided, of course, the observer has a precise idea as to where lies his north or south.

A wind vane should be placed perfectly clear of trees, buildings, or anything likely to deflect the course of the wind.

All wind direction observations should be recorded to the nearest point of the compass. To calculate the mean direction, it is usual to give an arbitrary numerical value to each observation, and then to analyse them.

Pressure and Velocity: Anemometers.—The instruments for the measurement of wind, either as regards pressure or velocity, are called *anemometers*. The earlier forms of these instruments were rectangular plates hung on hinges on a horizontal axis. The angle which these plates made with the vertical indicated the wind's pressure. In another kind,

the movements of the plates, resisted by either springs or weights, recorded upon a chart by means of a connected pencil the degree and amount of their displacement. In another form, the pressure of the wind is measured by making it blow into the open mouth of an open tube kept facing the current by means of a vane, and then noting the degree of pressure exerted upon a column of water or mercury in a U-tube. The later and better forms of anemometer in most general use are those known as Robinson's, consisting of four arms, each provided with a hollow cup and rotating horizontally on a vertical axis, which, by means of an endless screw, causes movements to be recorded on a series of dials in terms of miles and parts of a mile. These instruments are graduated on the principle that, allowing for friction, the cups revolve three times slower than the wind moves ; so that if the centres of the cups be, as they usually are, 1·12 feet apart, each revolution corresponds to 3·52 feet of movement, or 10·56 feet of actual wind-motion, and that 500 rotations of the cups indicate 1 mile of wind. Owing, however, to the allowance for friction being placed probably too high, and the cup motion being nearer two than three times slower than the wind, the velocity of wind movement, as recorded by many of these instruments in general use, is something like 20 per cent. too high. All anemometers to be reliable need to be kept scrupulously clean, well-oiled, and placed in a thoroughly open position at least 20 feet from the ground.

Estimation of Wind Force.—Various proposals have been made for estimating and describing roughly the force of the wind. The earliest was that of Admiral Beaufort, who, in 1806, devised a scale having a relation to the pressure of the wind upon the sails of a ship, and the amount of canvas which she could carry. Later attempts aim at expressing the wind's force as a pressure of so many pounds to the square foot. From experiments with various kinds of anemometers, Dines calculates the pressure (P) of the wind in pounds per square foot from the recorded velocity in miles per hour, on the assumption that the pressure equals one two-hundredth ($\frac{1}{200}$) of the square of the velocity, or $P = 0{\cdot}005 \times V^2$. According to this formula, a wind blowing with a velocity of 50 miles an hour exercises a pressure of $12\frac{1}{2}$ lb. on the square foot. Unfortunately for the value of this formula, the factor 200 is nearly as doubtful as that of three for the friction ratio of Robinson's anemometer.

Diurnal Variation of Wind.—In this country the wind has an average velocity of 8 miles an hour, and rarely exceeds 40 ; but its direction and force are subject to certain diurnal variations. As a rule, at mid-day the wind blows from sea to land, and from plains to hills, while in the evening the direction will be reversed.

In all parts of the world the upper air currents move faster than the lower, following in the northern hemisphere a direction slightly to the *right*. in the southern to the *left*. The lower current, under the influence of the upper, is deflected to the right in the northern hemisphere, to the left in the southern, and has its speed increased in both cases, while the upper, under the influence of the lower, is deflected in the opposite direction with diminution of velocity. These effects are naturally more marked the greater the diurnal heating of the lower strata relatively to the upper, and the greater the normal angle between the two currents. For these reasons : (1) Near the equator, and over the open sea, there is little diurnal variation of wind either in direction or speed. (2) On plains and similar land surfaces, even at great elevations, the wind shifts with the hands of the clock, and attains its maximum strength during the afternoon, backing and diminishing again at night in the northern hemisphere. The changes of direction are reversed

in the southern hemisphere. (3) On mountain peaks the wind shifts against the hands of the clock, and diminishes in strength during the afternoon, and veers and increases again at night. The changes in direction are reversed in the southern hemisphere.

ATMOSPHERIC ELECTRICITY.

It has been found that the atmosphere always contains free electricity, which is almost invariably positive. When the sky is cloudless, the electricity is always positive, but the intensity varies with the height, being greatest in the highest and most isolated situations. Positive electricity is only found at a certain height above the ground ; on flat ground it becomes manifest at a height of 5 feet. It is not found in houses, in streets, or under trees. The observations of negative electricity almost all occur during heavy rain. When the sky is clouded, the electricity is sometimes positive and sometimes negative, according to the electrified condition of the clouds. In relation to the atmosphere the earth's surface is always negative.

The electricity of the atmosphere is stronger in winter than in summer, increasing from June to January. It is subject to a double maximum and minimum each day. The first maximum occurs from 7 to 8 A.M. in summer, and from 10 A.M. to noon in winter ; it then falls slightly to the first minimum between 5 and 6 P.M. in summer, and between 2 and 3 P.M. in winter ; it rises to a second maximum a little after sunset, and then decreases to a second minimum which occurs about daybreak. These variations are best observed in clear settled weather. The chief sources of atmospheric electricity are the evaporation of impure water or water in which some degree of chemical decomposition takes place, the action of vegetation, combustion, and the friction caused by wind passing over terrestrial objects. Atmospheric electricity may, from time to time, reveal its presence by such unequivocal phenomena as thunderstorms, hailstones and aurora. But apart from these manifestations, the nature and intensity of electricity existing in the air under ordinary circumstances can be determined by such apparatus as the gold-leaf electroscope and various types of electrometer.

Thunderstorms are classified into Cyclonic Thunderstorms and Heat Thunderstorms. The former belong to winter and to insular climates, the latter to summer and to hot climates. *Cyclonic thunderstorms* are so called because they accompany atmospheric depressions, such as traverse the Atlantic and north-western coasts of Europe, especially in winter. While these cyclonic thunderstorms are not so violent, they are quite as dangerous as the summer thunderstorms, because in them the clouds drift at a low level, whereby the lightning is more likely to strike the ground (Moore).

Heat thunderstorms.—As a result of rapid evaporation, clouds surcharged with positive electricity form in the upper air. Subsequently, in the lower strata of the air, negatively electrified cloud strata form. The interaction of these cloud masses results in the phenomena of a thunderstorm. These heat thunderstorms show a diurnal and even an annual periodicity. It is not uncommon to find them breaking over the same line of country on consecutive days, as if there was a direct electrical attraction between the earth of certain localities and the superincumbent atmosphere for the time being ; and this no doubt is in reality the case.

Speaking generally, much negative electricity in the air forecasts rain ; on the other hand, a sudden development of positive electricity in wet weather is a certain sign of fine weather.

Hailstorms are modifications of the thunderstorm, and seldom occur during the night or in winter, but are most frequent in summer and during the hottest part of the day. *Hail* itself is intimately related to atmospheric electricity, its formation requiring (1) an excess of moisture, (2) a temperature below freezing, (3) the presence of electrified clouds. Typical hailstorms are nearly always associated with thunder and lightning, the hailstones being kept in a state of constant oscillation between two oppositely electrified clouds, until by continued condensation they grow so heavy that they fall to the earth.

Aurora.—This is an electrical phenomenon rarely seen in low latitudes, consisting of a luminous appearance in the northern and southern skies, most frequently in this hemisphere between the parallels of 66° and 75°. The aurora borealis is now generally considered to be due to positive electricity from the sea between the tropics being carried into the upper regions of the air, and thence wafted to the poles by the higher aerial currents. In the vicinity of the poles it descends towards the earth and meets the terrestrial negative electricity in a rarefied atmosphere. Luminous discharges then take place, being possibly increased in brightness by the presence of masses of ice-particles in the atmosphere (Marcet).

OZONE.

If a succession of electric sparks from a powerful electric machine be passed through a tube of oxygen, a peculiarly pungent odour is developed, due to the production of a body to which the name of ozone has been given, from the Greek ὄζω, *I have a smell.* Only a small proportion of oxygen can be converted into ozone by the electric discharge ; but a constant and considerable diminution of volume accompanies the change, 100 volumes of oxygen contracting to 92 volumes. Hence ozone must be denser than oxygen.

A popular opinion is, that a climate in which there is much ozone (*i.e.*, of the substance giving the reaction with potassium iodide and starch paper) is a healthy, and, to use a common phrase, an exciting one. The coincidence of excess of this reaction with pure air lends some support to this, but, like the former opinions, it still wants a sufficient experimental basis.

On the whole, the subject of the presence and effects of ozone is very uncertain at present ; experiments must be numerous, and inferences drawn from them need to be received with caution.

Determination of Ozone.—Papers saturated with a composition of iodide of potassium and starch, and exposed to the air, are supposed to indicate the amount of ozone present in the atmosphere. Schönbein, the discoverer of ozone, originally prepared such papers, and gave a scale by which the depth of blue tint was estimated. Subsequently, similar but more sensitive papers were prepared by Moffat, and Lowe afterwards improved on Moffat's papers, and also prepared some ozone powders.

The papers are exposed for a definite time to the air, if possible with the exclusion of light, and the alteration of colour is compared with a scale.

Schönbein's proportions are 1 part of *pure* iodide of potassium, 10 parts starch, and 200 parts of water ; Lowe's proportion is 1 part of iodide to 5 of starch ; Moffat's proportion is 1 to $2\frac{1}{2}$. The starch should be boiled for ten minutes, and filtered so that a clear solution is obtained ; the iodide is dissolved in another portion of water, and is gradually added. Both must be perfectly pure ; the best arrowroot should be used for starch.

When Schönbein's papers are used they are moistened with water after exposure, but before the tint is taken. Moffat's papers are similar, but do not require moistening with water.

The estimation of ozone is still in a very unsatisfactory state, and this arises from two circumstances.

(1) The fact that other substances beside ozone act on the iodide of potassium, especially nitrous acid, which is formed in some quantity during electrical storms. If such be suspected, in order to be quite sure that it is ozone only which has turned the paper blue, it is advisable to use a second test, which is to soak red litmus paper with a very dilute solution of the iodide of potassium. The potassium oxide produced causes an alkaline reaction, and turns the red paper to blue.

(2) The fact that the papers can scarcely be put under the same conditions from day to day; light, wind, humidity, and temperature (by expelling the free iodine) all affect the reaction.

HUMIDITY OF THE AIR.

The question of the amount of moisture in the air is somewhat complicated, and is usually spoken of as the degree of humidity. Reference has been made elsewhere to the fact that water is constantly evaporating into the air, and that the amount of water or moisture which the air can hold or retain is constantly varying with its temperature. When air is so full of moisture that it can contain no more, it is said to be saturated. In this country the air upon the average contains about three-fourths of the amount of water needed to saturate it, that is, it has a humidity of about 75 per cent.; but if the air containing this amount of moisture be cooled down, it will reach a temperature at which that same amount of moisture will suffice to saturate it, and if cooled still more it will reach a temperature insufficient to retain that moisture, with the result that it must part with some of it, the amount so parted with being precipitated or deposited as rain, snow, mist, or dew.

Mist, Fog, and Dew.—Aitken and some others have pointed out that occasionally, in perfectly pure air, a pressure of vapour may be maintained greater than that corresponding to the temperature of saturation. In fact, that condensation will not in general begin unless some nucleus is present to which the particles of water can attach themselves. It is on the presence of solid particles of dust in the air that the formation of mists and fogs depends; the precise degree of mist or fog depending on the amount of dust present, and on the size and constitution of the particles. When the number of dust particles is large or their size considerable, and the quantity of vapour condensed is small, we get the phenomenon of a town or so-called dry fog. The condensation of water upon invisible particles so increases their size as to make them visible. Often in the case of town fogs, their obviousness is not so much due to the action of the moisture condensed on the particles as to the excessive size and quantity of the particles themselves. What are known as sea fogs probably occur in air which is comparatively dry, because the dust in their case consists largely of salt grains derived from spray or surf, and which have a great affinity for moisture. If the quantity of condensed moisture is large, or the amount of dust and other solid nuclei small, we get what is called a mist, and it is merely a question of the degree of the moisture present which determines where the mist ends and actual rain begins.

The formation of dew is precisely analogous ; in this case the solid substance on which the moisture is precipitated or condensed is the surface of the ground, or a blade of grass, and not solid nuclei like soot or dust floating about in the air, as in the formation of fogs. Owing to the rapidity with which the earth, under certain circumstances, loses heat by radiation, as, for instance, on a fine clear night, the strata of air containing moisture, in contact with the cooling earth, themselves become reduced so much in temperature that they are no longer able to retain their water vapour, but actually lose it by condensation upon the ground, where it constitutes what we call dew. The particular temperature at which air saturated or loaded with moisture deposits its water is called the *dew-point.*

Hygrometers.—The amount of moisture present in the air is determined by means of instruments called hygrometers. Observations of the amount of moisture are taken in a direct and indirect manner. The most important instruments for direct observation are Daniell's and Regnault's hygrometers. The principle is the same in both, namely, to cool the air down to its saturation or dew-point.

Daniell's Hygrometer.—This consists of a bent tube with a globe at each end, and is partly filled with ether, the rest of the space in the tube being filled with the ether vapour, all the air having been expelled. One globe is made of blackened glass, and contains a thermometer, while the other is covered with muslin. Before using the instrument, the ether is made to pass into the blackened globe containing the thermometer, while the muslin surrounding the second globe is moistened with ether. This ether rapidly evaporates, causing a condensation of some of the ether vapour inside the tube ; this in its turn produces an evaporation of the ether in the blackened bulb. Now, whenever evaporation occurs, there is absorption of heat, so that the black bulb gradually becomes colder and colder, and the moment is soon reached when the air in contact with it begins to deposit dew on its surface. So soon as this happens, the temperature shown by the contained thermometer is read off and recorded as the dew-point.

Regnault's Hygrometer consists of a glass tube silvered at the bottom and for a portion of the way up. The tube is closed with a cork through which two holes are bored ; a narrow glass tube passing to the bottom of the silvered tube is introduced through one of the holes, and a thermometer is fixed in the other so that the bulb reaches nearly to the bottom of the silvered tube. There is a tubulure in the side of the silvered tube which is connected to an aspirator. The silvered tube is half filled with ether. When the aspirator is opened air bubbles through the ether and causes it to volatilise, and by so doing so reduces the temperature that dew is deposited on the outside of the silvered tube, at which instant the temperature of the contained thermometer is read off as that of the dew-point.

Of indirect hygrometers there are two principal kinds, namely the hair hygrometer of Saussure, and the wet and dry bulb thermometer.

Saussure's Hygrometer consists of a human hair that has not been roughly handled, and that has been freed from grease by digestion in ether or liquor potassæ. Such a hair elongates when moist and contracts when dry. It is fixed at one end, and stretched by a small weight at the other, the connecting cord being passed round a pulley to which is attached an arm or pointer marking on a scale. This scale is graduated by wetting the hair to complete saturation, and marking the point 100, then placing it over sulphuric acid and marking 15° of saturation ; the intervening space is then marked off in degrees, indicating degrees of relative humidity. This instrument is fairly sensitive, but needs frequent comparison and verifi-

cation with a more precise hygrometer. Wolpert's hygrometer is of horse-hair.

The wet and dry bulb thermometer, or *psychrometer*, really consists of two ordinary thermometers mounted on a frame side by side. One of these has its bulb covered with muslin, and is kept constantly moist by being connected with a small vessel containing distilled water, by means of the capillary action of a piece of cotton wick, which has been previously well freed from grease by being boiled in ether. The dry bulb gives, of course, the temperature of the air, while the wet one, in consequence of the evaporation constantly going on from its surface, gives a lower reading. The difference between the two temperatures recorded indicates the rapidity with which evaporation is proceeding, and, moreover, since evaporation is faster as the air is drier, the indication of the degree of evaporation is a measure of the dryness or moistness (otherwise humidity) of the air. If the air be saturated with moisture, of course no evaporation is going on, and the two thermometers will record the same temperature. In frosty weather, frequently the muslin covering and the water in the vessel will freeze, with the result that evaporation will not take place. In such case, it suffices to brush the frozen muslin over with a brush dipped in cold water and allow this to freeze; at such time evaporation will be going on from the ice-surface, so that it will be equivalent to its having a damp but unfrozen bulb. Occasionally in thick fog, or during very damp cold weather, the wet bulb may read higher than the dry; the latter temperature is then to be taken as that of saturation.

Glaisher's Factors.

Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.
10	8·78	33	3·01	56	1·94	79	1·69
11	8·78	34	2·77	57	1·92	80	1·68
12	8·78	35	2·60	58	1·90	81	1·68
13	8·77	36	2·50	59	1·89	82	1·67
14	8·76	37	2·42	60	1·88	83	1·67
15	8·75	38	2·36	61	1·87	84	1·66
16	8·70	39	2·32	62	1·86	85	1·65
17	8·62	40	2·29	63	1·85	86	1·65
18	8·50	41	2·26	64	1·83	87	1·64
19	8·34	42	2·23	65	1·82	88	1·64
20	8·14	43	2·20	66	1·81	89	1·63
21	7·88	44	2·18	67	1·80	90	1·63
22	7·60	45	2·16	68	1·79	91	1·62
23	7·28	46	2·14	69	1·78	92	1·62
24	6·92	47	2·12	70	1·77	93	1·61
25	6·53	48	2·10	71	1·76	94	1·60
26	6·08	49	2·08	72	1·75	95	1·60
27	5·61	50	2·06	73	1·74	96	1·59
28	5·12	51	2·04	74	1·73	97	1·59
29	4·63	52	2·02	75	1·72	98	1·58
30	4·15	53	2·00	76	1·71	99	1·58
31	3·60	54	1·98	77	1·70	100	1·57
32	3·32	55	1·96	78	1·69		

From the respective readings of the wet and dry bulb thermometers many valuable deductions may be made; for example, the dew-point, the tension or elastic force of vapour (or the amount of barometric pressure due to the vapour in the air), the relative humidity, the weight of vapour in a cubic foot of air, the amount of vapour required to saturate the air, and the weight of a cubic foot of air at the prevailing atmospheric pressure.

Calculation of the Dew-Point.—The dew-point has already been explained as being that temperature at which the air is saturated with moisture, so that the least further fall in temperature causes a deposit of water in the form of dew. Its determination is obvious by means of a direct hygrometer; its calculation from the readings of the dry and wet bulb thermometers can be roughly made by taking it to be as much below the wet bulb reading as that is itself below the dry; but for greater accuracy it is better calculated out in the following way:—

By Glaisher's Factors.—By comparison of the results of Daniell's hygrometer and the dry and wet bulb thermometers for a long term of years, Glaisher deduced an empirical formula, which is thus worked: Take the difference of the dry and wet bulbs, and multiply it by the factor which stands opposite the *dry-bulb* temperature in the Table on page 855, deduct the product from the *dry-bulb* temperature; the result is the dew-point. From this formula Glaisher's tables are calculated.

Elastic Force of Vapour.—In an atmosphere of pure steam or aqueous vapour its force, or tension, at the earth's surface is the pressure it exerts—that is, its weight. So, in an atmosphere composed partly of dry air and partly of steam or vapour, the elastic force of each is the weight of each. This is commonly expressed either in inches or millimetres of mercury. It is conveniently calculated by direct reference to the following Table. To express inches as millimetres multiply by 25·4.

Temp. Fahr.	Tension in inches of Mercury.	Temp. Fahr.	Tension in inches of Mercury.	Temp. Fahr.	Tension in inches of Mercury.	Temp. Fahr.	Tension of inches in Mercury.
0	0·044	24	0·129	48	0·335	72	0·785
1	0·046	25	0·135	49	0·348	73	0·812
2	0·048	26	0·141	50	0·361	74	0·840
3	0·050	27	0·147	51	0·374	75	0·868
4	0·052	28	0·153	52	0·388	76	0·897
5	0·054	29	0·160	53	0·403	77	0·927
6	0·057	30	0·167	54	0·418	78	0·958
7	0·060	31	0·174	55	0·433	79	0·990
8	0·062	32	0·181	56	0·449	80	1·023
9	0·065	33	0·188	57	0·465	81	1·057
10	0·068	34	0·196	58	0·482	82	1·092
11	0·071	35	0·204	59	0·500	83	1·128
12	0·074	36	0·212	60	0·518	84	1·165
13	0·078	37	0·220	61	0·537	85	1·203
14	0·082	38	0·229	62	0·556	86	1·242
15	0·086	39	0·238	63	0·576	87	1·282
16	0·090	40	0·247	64	0·596	88	1·323
17	0·094	41	0·257	65	0·617	89	1·366
18	0·098	42	0·267	66	0·639	90	1·410
19	0·103	43	0·277	67	0·661	91	1·455
20	0·108	44	0·288	68	0·684	92	1·501
21	0·113	45	0·299	69	0·708	93	1·548
22	0·118	46	0·311	70	0·733	94	1·596
23	0·123	47	0·323	71	0·759	95	1·646

The tension or elastic force of vapour represents the pressure of all the aqueous vapour in the air above the place of observation. It is greatest near the equator, least near the poles; greater over the ocean than over dry land, in summer than in winter, by day than by night, and at sea-level than in the upper strata of the atmosphere.

Relative Humidity.—This is merely a convenient term used to express comparative dryness or moisture. Complete saturation being assumed to be 100, any degree of dryness may be expressed as a percentage of this, and

is obtained at once by dividing the weight of vapour actually existing by the weight of vapour which would have been present had the air been saturated. In other words, the hygrometric state or relative humidity (H) may be expressed as the ratio of the elastic force of aqueous vapour at the temperature of the air (E) to the elastic force of the vapour at the temperature of the dew-point (e); that is, $H = \frac{e}{E} \times 100$.

To find the relative humidity, therefore, we require to know, (1) the actual temperature of the air; (2) the dew-point; (3) the elastic tension of vapour present in the air, which is the tension of the dew-point, and is found in the table of tensions; (4) the tension of vapour saturated at the air temperature also found in the table.

Example.—The dry-bulb thermometer reads 62° F., the wet bulb 56° F.; required the relative humidity. The dew-point $= 62 - \{(62 - 56) \times 1{\cdot}86\} = 50°{\cdot}84$.

A reference to the table shows the tension at 62°, or the tension which would exist if the air were saturated with moisture, to be 0·556 in. (E); the same table gives the tension of vapour actually present in the air, or the tension at the temperature of the dew-point, 50°·84, to be 0.372 (e). From these facts, H or the relative humidity $= \frac{0{\cdot}372}{0{\cdot}556} \times 100$, or 66·9, say 67 per cent. of saturation.

Relative humidity is greatest near the surface of the earth during night, when the temperature, being at or near the daily minimum, approaches the dew-point; it is also great in the morning, when the sun's rays have evaporated the dew, and the vapour is as yet only diffused a little way upwards; and it is least during the greatest heat of the day (Buchan). This percentage saturation of the air is practically an inverse measure of the drying power of the air, and as such has a most important bearing upon climatic conditions, more particularly the degree of radiation from the earth's surface. We are all familiar with the peculiarly unpleasant effects of a hot moist atmosphere, and with the invigorating influence of dry and crisp air. A saturated atmosphere at from 35° to 50° F. will be found to be intolerably chilly, and although the evaporation may be checked, and this source of heat-loss removed, yet the conduction and radiation due to the vapour in the air will be enormous. A temperature of 50° to 65° F. in a nearly saturated atmosphere seems to be not uncomfortable, as under those conditions an equilibrium seems to be established between the cooling action by conduction and radiation, due to the vapour in the air, and the supply of heat from checked skin evaporation. A saturated atmosphere with a temperature of from 65° to 80° F. becomes oppressive and sultry. Above 80° F. a saturated air becomes most oppressive, and it is doubtful whether life could be long sustained in a saturated atmosphere of 90° to 100° F., as the surplus heat cannot be removed by conduction or radiation, while at the same time the natural effort of the system to produce evaporation is enormously exaggerated. Humidity of the air is very generally supposed to be associated with the spread, or rather prevalence, of disease; much moisture in the air certainly favours the continuance of colds, but at the same time appears to relieve bronchitis by assisting expectoration and the general discharge of mucus.

The differences between the temperatures marked in the sun and shade by two maximum thermometers are chiefly dependent on the amount of humidity. The maxima of insolation (measured by the difference between the sun and shade thermometers) occur in those stations and on those days when humidity is greatest. Thus, at Calcutta, the relative humidity being 80 to 93, the insolation (or difference between the thermometers) is 50° F.;

at Bellari, the relative humidity being 60 to 65, the insolation is 8° to 11° F. These results are explained by Tyndall's observations, which show that the transparent humidity will scarcely affect the sun's rays striking on the sun thermometer, while it greatly obstructs the radiation of invisible heat from the thermometer ; when the air is highly charged with moisture, the sun thermometer is constantly gaining heat from the sun's rays, while it loses little by radiation, or, if it does lose by radiation, gains it again from the air.

The daily variations in atmospheric humidity are often considerable. The accompanying diagrams * show the average condition of the air as regards relative wetness or dryness at each hour of the day and night, with the mean values for the day in figures, for four observations in connection

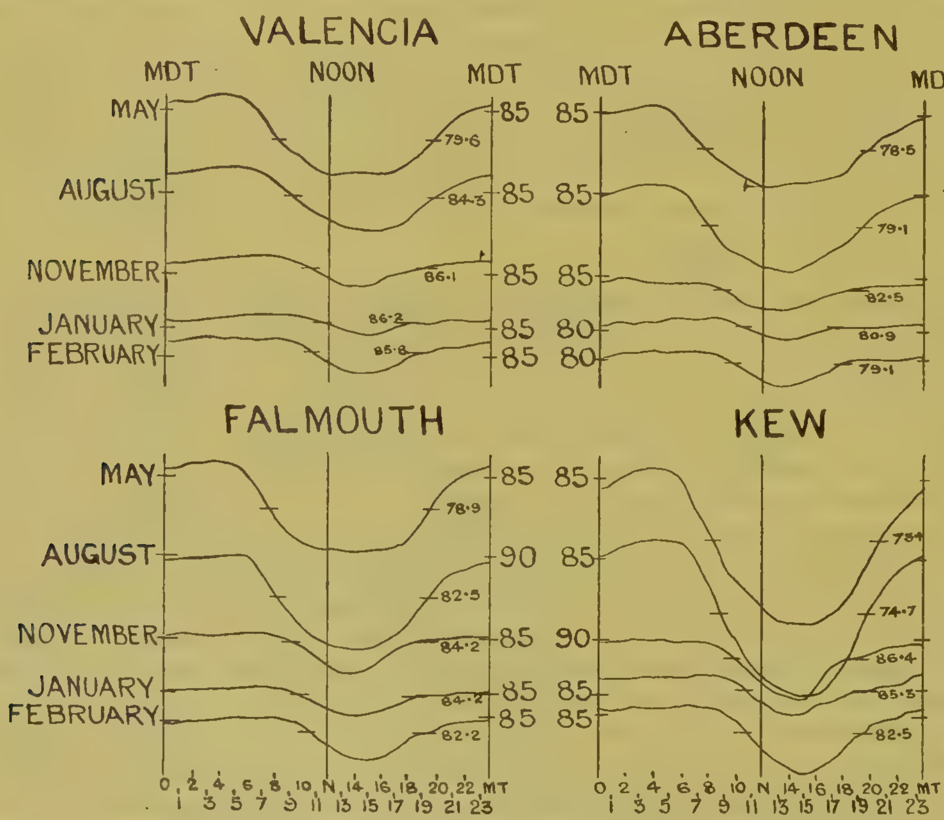


FIG. 171.—CHART SHOWING VARIATIONS IN HUMIDITY (AFTER SHAW).

with the Meteorological Office, and for the months of January, February, May, August and November. The curves are based on the records for fifteen years. The results are certainly striking and show extreme fluctuations within twenty-four hours in every season of the year. These fluctuations are mainly due to the diurnal variations of temperature, while some of the more rapid oscillations are attributable probably to passing intervals of sunshine. As bearing on the hygienic aspects of the question, it is conceivable that, in the absence of any direct evidence about humidity, the temporary dryness of high day temperatures may be made useful even in cold weather, if the corresponding dampness of the night be avoided by staying indoors.

The Weight of Air.—At a given temperature, pressure and humidity can be determined from similar data. Thus, say it is required to know the weight of a cubic foot of air containing 60 per cent. of moisture at 60° F.

* W. N. Shaw: "Climate and Health," *Journ. Royal San. Institute*, 1906, vol. xxvii. p. 527.

and under 29·92 inches barometric pressure. Now, a cubic foot of moist air, such as this, is nothing more than a mixture of (1) a cubic foot of dry air at 60° F., under the existing barometric pressure *minus* the tension of the vapour present, and (2) a cubic foot of watery vapour at that temperature. The tension of the vapour present will be that corresponding to the vapour pressure at the dew-point. Reference to the Table of aqueous vapour tensions on page 856 shows that the maximum tension of vapour at 60° F. is 0·518 inch, and the relative humidity being 60 per cent., the maximum vapour pressure at the dew-point, or actual vapour tension in the air, is 0·518 × 0·6 or 0·31 inch. As the barometer stands at 29·92 inches, therefore 29·92 *minus* 0·31 or 29·61 inches would be supported by the pressure of the dry air, and the remaining 0·31 inch by the vapour. Now, the weight of a cubic foot of dry air at 32° F. and 29·92 inches is 566·85 grains; and remembering that density varies inversely as absolute temperature, and directly as pressure, it is obvious that the weight of one cubic foot of dry air at 60° F. and 29.61 inches will be

$$\frac{566 \cdot 85 \times 29 \cdot 61}{29 \cdot 92 \times (1 + (0 \cdot 002036) \times (60 - 32))} = 530 \cdot 72 \text{ grains (see page 138).}$$

The weight of a cubic foot of vapour at 60° F. is 5·77 grains, but as the relative humidity is 60 per cent., its weight under those circumstances is 5·77 × 0·6 or 3·46. The weight of the cubic foot of air containing 60 per cent. of moisture at 60° F. will, therefore, be 530·72 *plus* 3·46 or 534·18 grains.

CLOUDS.

A cloud is a collection of particles of aqueous vapour condensed into watery particles and floating in the atmosphere at some height above the ground. This height varies from a few hundred feet to several miles.

The "cloud line," or that level below which cloud formations seldom or never take place, varies in different parts of the world. In South America it is about 9000 feet; in the Tyrol it falls to about 5000 feet; and in the British Islands it is as low as 2500 feet.

Classification of Clouds.—The following is the cloud classification of Hildebransson and Abercromby, as now universally accepted. Those marked with (*a*) are detached or rounded forms, most frequently seen in dry weather; those marked with (*b*) are wide-spread or veil-like forms, most frequent in wet weather,

A. Highest clouds, mean height 9000 metres.
- (*a*) 1. Cirrus.
- (*b*) 2. Cirro-stratus.

B. Clouds of mean altitude, 3000–7000 metres.
- 3. Cirro-cumulus.
- (*a*) 4 Alto-cumulus.
- (*b*) 5. Alto-stratus.

C. Low clouds, below 2000 metres.
- (*a*) 6. Strato-cumulus.
- (*b*) 7. Nimbus.

D. Clouds formed by the diurnal ascending currents.
- 8. Cumulus. Top, 1800 metres; base, 1400 metres.
- 9. Cumulus-nimbus. Top, 3000–8000 metres; base, 1400 metres.

E. Elevated fog, below 1000 metres.
- 10. Stratus.

RAINFALL.

Many physical causes are concerned in the production of rain. If air laden with aqueous vapour ascends into the higher regions of the atmosphere, it expands, owing to the diminished pressure, and consequently becomes cold, producing a condensation of vapour. A hot, moist current of air mixing with a colder vapour undergoes cooling, which brings about a condensation of the vapour. "When the individual vapour-vesicles become larger and heavier by the constant condensation of aqueous vapour and when finally individual vesicles unite, they form regular drops, which fall as rain."

Of the more immediate causes producing rain, winds are the most important. Winds blowing from high latitudes to low ones are generally dry, those moving in the opposite direction are generally moist. Winds blowing off shore are dry, those blowing from the sea are damp. For these reasons we find the wettest regions of the globe to be the equatorial belt of calms, and certain localities where damp winds meet mountain ranges, and are there suddenly chilled. The greatest rainfalls known are on the Western Ghâts on the Malabar coast of India, as at Mahableshwar, where the fall is 263 inches yearly; so again at Cherrapunji, in the Khasia hills to the north of the Bay of Bengal, the rainfall averages 600 inches annually—in 1861 it was as much as 805 inches. Even in our own country the warm moist air over the Gulf Stream, impinging on the Cumberland Hills, causes, in some districts, a fall of 80, 100, 150, or even more inches in the year. On the other hand, the regions with least rainfall are the desert tract reaching from the Sahara through Arabia and Persia to Central Asia, the Kalahari desert in South Africa, and the Great Salt Lake region in North America.

The amount of rain which falls varies, of course, very much with the place; but in determining the average fall at any station, it is necessary to deal with observations extending over long periods.

The average fall of rain in England and Wales is 37·4 inches annually; in Scotland it is 43·2, and in Ireland 38·6 inches On the east coast of England about 21 inches of rain falls in a year, while on the west coasts of both Scotland and Ireland it averages from 60 to 80 inches; in some parts of Cumberland as much as 150 inches a year have been known to fall. It is very rarely that more than 1 inch of rain falls anywhere in Great Britain in one day; though occasionally as much as 5 inches have been known to fall. For furnishing meteorological returns, a minimum record of 0·01 inch is considered as characteristic of a rainy day in this country.

Observation of Rainfall.—Rain is estimated in inches; that is, the fall of an inch of rain implies that on a given area, say a square yard of surface, rain has fallen equal to an inch in depth. The amount of rain is determined by a rain-gauge.

The most convenient rain-gauge for practical purposes consists of a copper or japanned tin cylinder, at the upper end of which is fixed a turned brass ring with a sharp edge whose diameter is accurately known (Fig. 172). Some 6 inches below the ring the cylinder narrows to a funnel, terminating in a long and narrow tube which leads to a metal collecting vessel. Very often the lower end of this tube is curled upward to check evaporation. In this country a rain-gauge is usually circular, with a diameter of either 5 or 8 inches, so that its area in square inches is accurately known. The rain, having been collected in the receiver, is measured in a graduated glass vessel, the divisions of which correspond to hundredths of an inch. The measuring

vessel is divided proportionately to the area of the gauge, the diameter of which should always be some simple unit, like 5 or 8 inches, so that, if the original measure get broken, a new one can be readily improvised and graduated. Thus take an 8-inch gauge, the diameter being 8 inches, its receiving area is 50·26 square inches; therefore 1 inch of rainfall, or rain 1 inch deep over a town, would deposit in that particular rain-gauge 50·26 cubic inches of water, or 29 fluid ounces, or 12,688 grains of water. It is found in practice more convenient to make the measuring glass hold half an inch. Therefore, if $14\frac{1}{2}$ fluid ounces, or 6344 grains, of water be poured into the proposed measuring glass, and the vessel be marked with a line at the level of its top, that line will represent the graduation of 0·5 inch of rain; fifty subdivision markings are similarly made, or one for each $\frac{1}{100}$th inch of rain, the graduations being marked at 0·10, 0·20, 0·30, 0·40 and 0·50.

The best place for a rain-gauge is on the ground in a well-exposed position, with the rim about 1 foot above the earth. A rain-gauge should never be placed upon a house roof, unless, as in towns, no sufficiently open space is available. The spot on which a rain-gauge is exposed should be clear of all objects whose height is greater than their distance from the gauge. Rain should not be collected in the measuring glass, as this is liable to break, especially during frosts. Snow or hail can be measured by thawing the quantity collected and measuring the water which results. When snow falls, its measurement demands constant attention. Should the wind be high and the temperature very low, drifting of snow dust will be apt to vitiate the measurements. Snow will be drifted into the gauge on the one hand, or blown out of it on the other. The depth of snow in a sheltered place, free from drifting, should be carefully measured by a two-foot rule. On a very rough estimate, 1 foot of dry snow may be taken to represent an inch of rain. Should the snow have been lifted out of the funnel by the wind, a good plan is to take the outside cylinder of the gauge, which has the same diameter as the funnel, and to insert it in the snow where it lies level and of a uniform depth. The solid cylinder or section of snow, thus cut out, should then be melted and the resulting water measured.

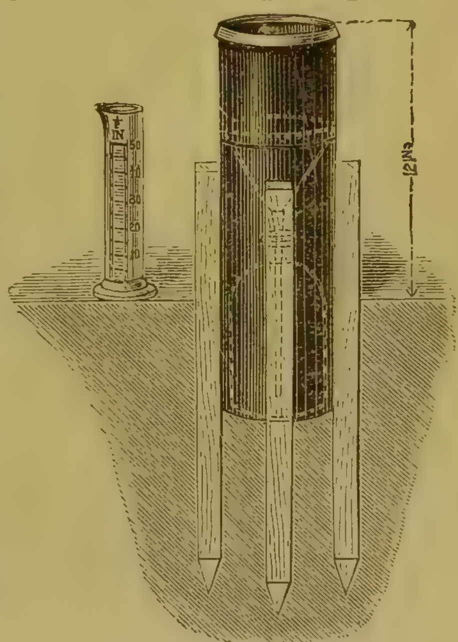


FIG. 172.—RAIN-GAUGE.

All observations should be made every day at 9 A.M., and the amount collected entered as having fallen on the previous day.

Seasonal and Diurnal Fall of Rain.—In these islands and on the western shores of Europe the winter rainfall exceeds that of summer. This is mainly due to the prevalence of westerly winds laden with moisture, and to the relative coldness of the highlands and coast-line on the Atlantic sea-board. In the middle of Europe the summer rainfall is in excess of that in winter, apparently owing to the heavy rains which accompany summer thunderstorms. These summer rains are really evaporation rains which fall from cumuli formed by evaporation and their ascent above the saturation or condensation line. The seasonal rains of India, accompanying the south-west monsoon, are caused by the condensation of the vapour in

those winds blowing in from over the Indian Ocean, condensing against the cold highlands of the Himalayas.

The diurnal fall of rain is dependent on season. As a rule, in winter more rain falls by night than by day, while in summer the reverse is the case; in spring and autumn there is not much difference. According to Hellmann, the diurnal variation of rainfall, like that of cloudiness, can be classified according to a number of typical curves. An afternoon maximum occurs in many places, especially in summer, corresponding to the hour of maximum frequency of thunderstorms; and another maximum late at night or in the very early hours of the morning is connected with peculiarities in the diurnal variations of pressure, temperature, and even wind. This latter maximum is more or less characteristic of Western Europe, at all seasons, and is specially marked in winter.

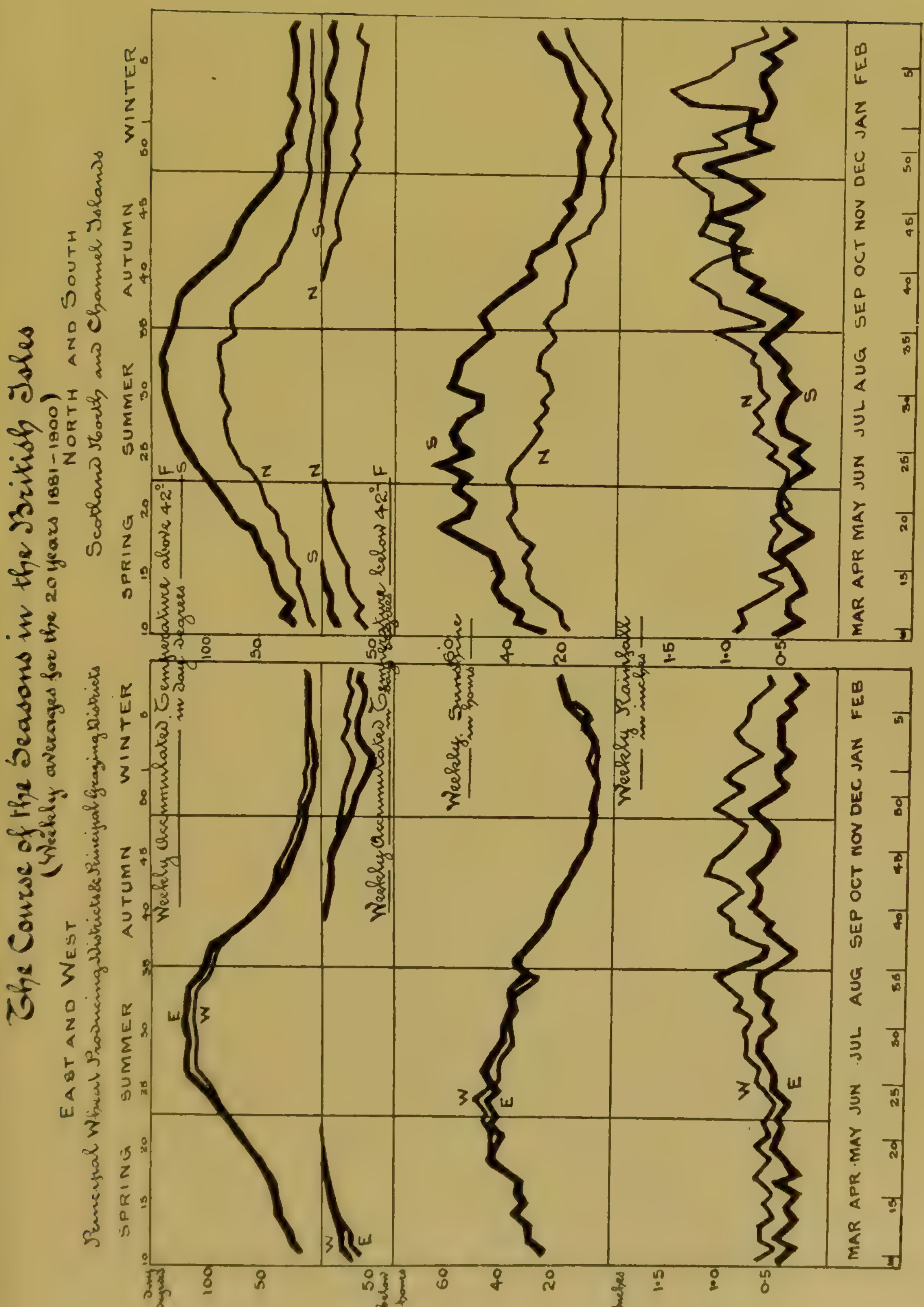
As illustrative of some of the variations of the meteorological elements, a reference may be made to the accompanying chart (Plate XX.), modified from an interesting paper by W. N. Shaw,* in which the average seasonal variation of rainfall, sunshine and temperature over certain main divisions of the British Isles is shown. The statistics as to temperature are indicated by the number of accumulated day-degrees above or below 42° F.; thus the figures show the aggregate warmth or coolness of the week or the season, as estimated by its intensity and duration, using 42° F. as a datum line. The most disagreeable types of weather in our climate are those associated with temperature between 42° F. and the freezing-point. Dry cold is rare in this country, the most common variety being below 42° F. associated with much moisture. The diagram shows the weekly average values, and the variations are considerable, even when one is dealing with the averages of twenty years.

Another aspect of the same question is shown in Plate XXI., representing two meteorological sections across the British Isles; one is from north to south, the other from west to east, and upon them are marked the approximate height of the land, the rainfall, the maximum temperature and the minimum temperature at the several stations as given by the average of a number of years. They are also slightly modified from a paper by W. N. Shaw.† Figures for two months, February and August, are represented, and it will be noticed how the average maximum and minimum temperatures diverge as the line moves inland from the sea. On the west to east diagram we may note especially (1) the increase of rainfall as one passes from the coast inland, and the gradual diminution as one passes eastward from the high land; (2) the manner in which this effect of geographical distribution fades in the summer months as compared with the winter; (3) the gradual increase of warmth in summer and of cold in winter as one travels eastward along the same line; (4) as regards the north to south line, the comparative uniformity of conditions for all the elements. The general conclusion to be drawn from the diagrams is, that although the difference of locality and season can be identified easily, there is no very marked distinctions between the climates of the British Isles, and that, in technical language, the incidents of weather are really of more importance than climate, except as regards certain specially mountainous regions. It is a pity that the particulars as to the atmospheric moisture could not be included in the diagrams, but the data were not available.

* W. N. Shaw: see *Journ. Royal Statistical Society*, 1905, vol. lxviii. part ii.

† W. N. Shaw: "Climate and Health," *Journ. of the Royal San. Institute*, 1906, vol. xxvii. p. 517.

PLATE XX


The Course of the Seasons in the British Isles
(Weekly averages for the 20 years 1881–1900)
EAST AND WEST
Principal Wheat Producing Districts & Principal Grazing Districts
NORTH AND SOUTH
Scotland North and Channel Islands
SPRING SUMMER AUTUMN WINTER
Weekly Accumulated Temperature above 42° F in day degrees
Weekly Accumulated Temperature below 42° F in day degrees
Weekly Sunshine in hours
Weekly Rainfall in inches
Day degrees
50 below
hours
Inches
MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB

ATMOSPHERIC PRESSURE.

We have already seen in Chapter II. that the atmosphere has weight, and by virtue of that weight exercises pressure. The instrument used for ascertaining this effect is called the barometer (βάρος, *weight*; μέτρον, *a measure*), so called because it measures the weight of the atmosphere from the height of a column of mercury or other liquid supported by the pressure of the atmosphere. The heights of the columns of two fluids in equilibrium are inversely as their specific gravities; and since, in terms of mercury at sea-level in this country, the atmospheric column equals that of 29·92 cubic inches of mercury; and since 1 cubic inch of mercury weighs 3426¾ grains the weight of 29·92 cubic inches will be 14·64 lb. Thus the pressure of the atmosphere generally on a square inch of the earth's surface is 14·64 lb. The pressure of the atmosphere is not expressed by the weight of the mercury sustained by that pressure, but by the perpendicular height of the column. Thus, when the height of the column is 29.92 inches, we do not say that the atmospheric pressure is 14·64 lb. on the square inch, but that it is 29·92 inches, meaning that the pressure will sustain a column of mercury at that height. In this country and America the usual measurement is by inches, tenths, and hundredths; on the Continent, and for scientific observations everywhere, the metrical system is adopted; the standard pressures at sea-level being taken as 29·92 inches and 760 millimetres respectively, at standard temperatures of 32° F. and 0° C.

Barometers.—These are usually either mercurial, glycerine, water, or aneroid barometers. As commonly constructed, the mercurial barometer consists of a tube of glass about 33 inches long, closed at one end, filled with mercury and placed vertically with the open end dipping into a cup containing mercury, called the cistern. As the mercury in the tube balances, as it were, the pressure of the air, it is obvious that it falls with a lessened pressure, but rises with an increased pressure. Since, when the mercury column falls, some mercury flows out of the tube into the cistern, and when it rises out of the cistern into the tube, the level of the mercury surface in the cistern varies with every change of pressure; either some means must be adopted for adjusting either the zero end of the scale, which marks the height of the vertical column, to the mercury surface in the cistern, or the mercury surface to the zero end of the scale, or else some proper allowance must be made for the error introduced in the absence of such adjustment. In certain common forms of barometer the scale is laid off from a zero at some fixed point in the cistern, with the result that, except at one particular point, the instrument reads wrongly, because, during the changes which take place in the length of the column, the level of the mercury in the cistern also changes, being sometimes higher and sometimes lower than the fixed zero point. In order to overcome this difficulty and source of error, various expedients have been resorted to so as to compensate for the ever changing level of the mercury in the cistern; thus:—

(1) By a so-called capacity correction which, duly noted and recorded on the scale by the maker, states the ratio of the interior area of the tube to that of the cistern; thus, capacity $\frac{1}{16}$. To apply this correction, there is always marked on the scale a certain height of the column which is correctly measured by the scale. This exact height is termed the *neutral point*; when the mercury sinks below this, the height read off will, of course, be too great, because the level of the mercury in the cistern will have risen above the zero in a proportionate amount; for the same reason, when the mercury

rises above the neutral point, the reading will be too small, because the level of the mercury in the cistern will have fallen below the zero of the scale. The capacity correction is applied by taking the indicated fractional part of the difference between the height read off and that of the neutral point, and adding or subtracting it from the reading, as the case may be. Thus, suppose in the case of a barometer marked with a neutral point, and with a capacity correction of $\frac{1}{50}$, the mercury stands 1 inch above the neutral point, then $\frac{1}{50}$ of the difference the height read off and the neutral point, or, in this case, one-fiftieth or 0·02 inch, must be added to the observed reading.

(2) In the Kew barometers the error is obviated by graduating the scale in nominal inches, which are shorter than true inches, from above downwards in proportion to the relative size of the diameter of the tube and cistern; the highest point on the scale, say 32 inches, being marked off correctly from a definite point on the cistern side. As in the ordinary Kew barometers these diameters measure about 0·25 and 1·25 inch respectively, the inches of the scale are shortened in the proportion of 0·04 inch to 1 inch.

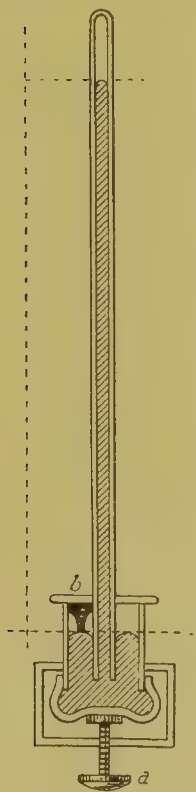


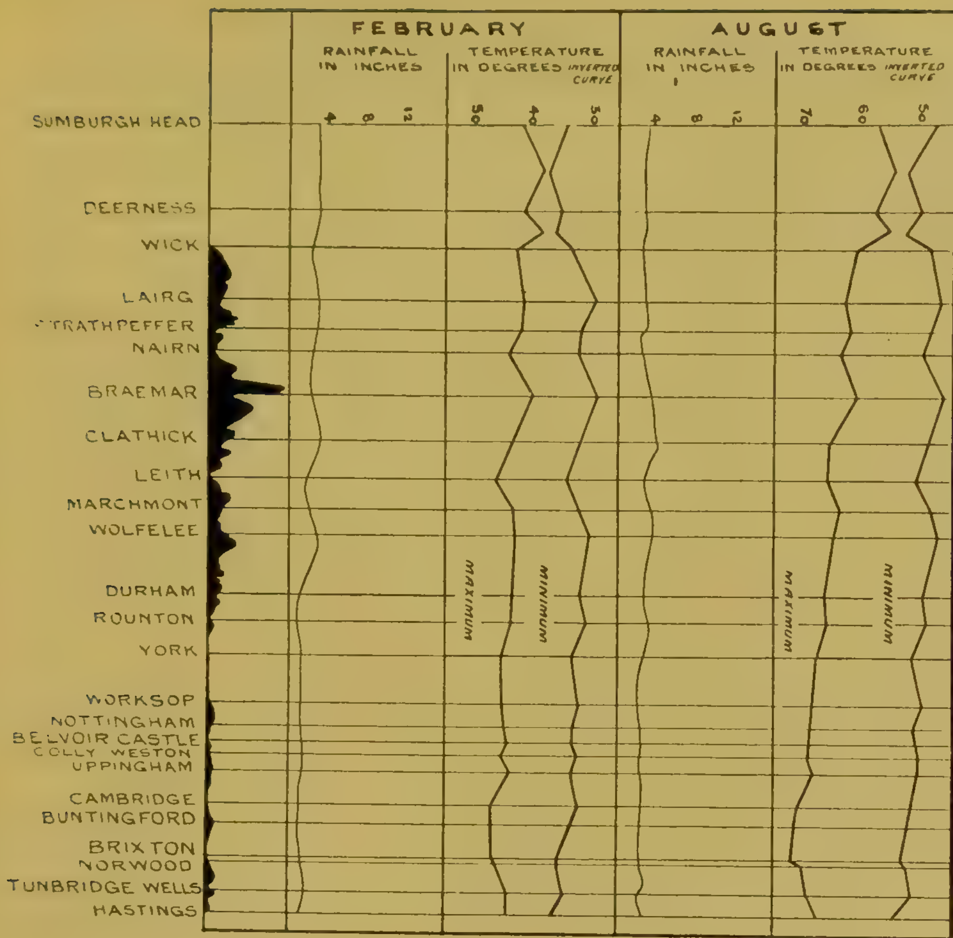
Fig. 173.
Diagram of a Fortin's Barometer.

(3) Another device is to do away with the cistern altogether, and to employ a U-shaped tube, in which one arm is shorter than another, and open at one end. Both levels are read upon a scale, and the reading of the barometer is the difference in level of the mercury in the two legs. These are sometimes called siphon barometers, of which the ordinary wheel barometer is a common type; in this latter instrument the movements of the mercury are transmitted from a float on the mercury in the open tube, by means of a string, to an axis which carries an index moving over a dial plate as in a clock.

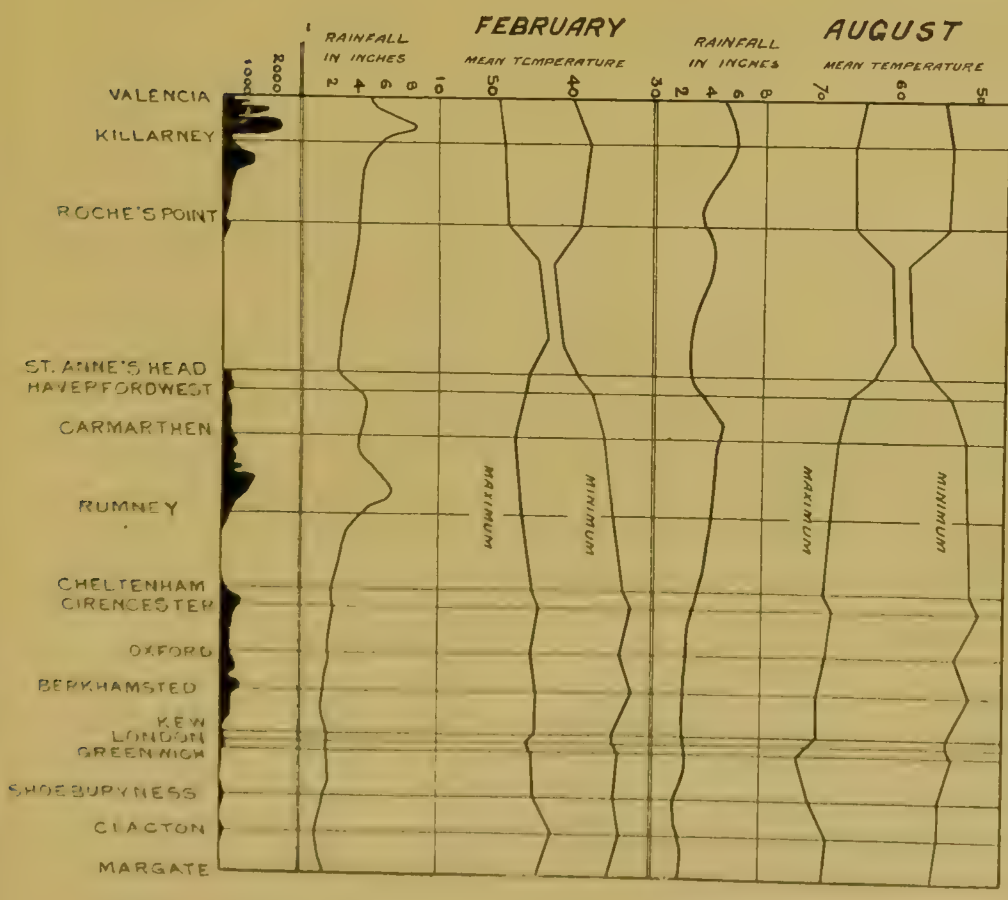
(4) In what are called the Fortin barometers, or standard barometers, the necessity for capacity correction, or either of the other above-named devices, is avoided by giving the cistern a pliable base of leather, capable of being raised or lowered by means of a screw *a* (Fig. 173). The upper part of the cistern is made of glass, through which the zero of the scale can be seen as a piece of ivory, whose lower extremity is called the *fiducial point*, *b*. Before taking a reading, the level of the mercury in the cistern must be set exactly to this point, by raising or lowering the cistern base by means of the screw; since the fiducial point is the tip of the piece of ivory, and accurately corresponds, as a fixed point, to the zero of the scale, after the level of the mercury in the cistern has once been carefully adjusted to it, it is obvious that the height of the column of mercury then read will be an accurate measure of the atmospheric pressure.

Although in the majority of barometers the atmospheric pressure is measured by a column of mercury because of its high specific gravity, still, in some others, other liquids are employed, such as *glycerine*, which, having a lower specific gravity, is much more sensitive to variations in pressure. The specific gravity or density of mercury is 13·59, while that of glycerine is but 1·26; the atmosphere we know can support a mercurial column 29·92 inches high; therefore, it can equally support a glycerine column 27 feet high; or, in other words, a fall of 1 inch in a mercurial column is the equivalent of a fall of 10·7 inches in a glycerine instrument—the latter, in

PLATE XXI



METEOROLOGICAL SECTION. SUMBURGH HEAD TO HASTINGS
AVERAGE VALUES
North to South



METEOROLOGICAL SECTION VALENCIA TO MARGATE
AVERAGE VALUES
West to East

consequence of its greater range, being far more sensitive as an indicator. The advantage of the glycerine barometer is that it not only magnifies tenfold, as it were, the readings of the mercurial instrument, but the medium used, while undiluted, does not freeze at any known terrestrial temperature. Jordan's glycerine barometer, used at the *Times* Office, London, consists of a gas tube, five-eighths of an inch in diameter and 28 feet in height. As glycerine has a marked affinity for water, the glycerine in the cistern of this gigantic barometer is covered with a layer of paraffin oil.

Water barometers have also been made, in which the column required to balance the atmosphere is 34 feet. These are obviously very sensitive, but unsuitable for general use, owing to the high freezing-point of water, and the liability to condensation of its vapour.

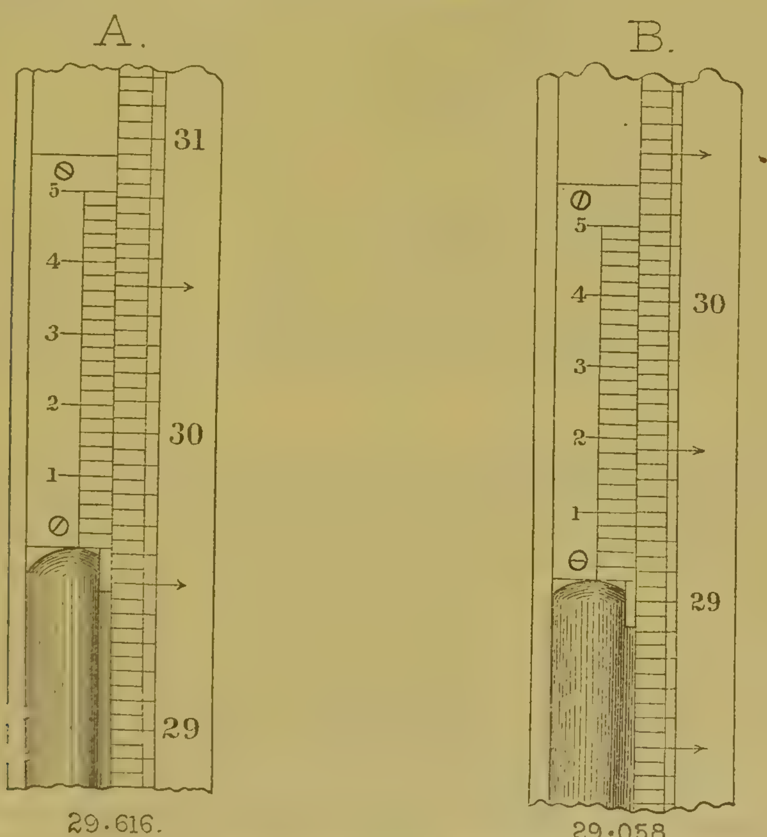


FIG. 174.—BAROMETRIC SCALES WITH VERNIER.

Besides mercurial, glycerine and water barometers, familiar instruments in common use are *aneroid barometers.* These are small air-tight metallic boxes, from which the air has been exhausted, and so constructed that as the atmospheric pressure rises, so the metal box is forced in, and, helped by means of a strong spring, bulges out again when the pressure lessens. By an arrangement of levers, the movements of the metal are made to turn an index on a dial face, and are so exaggerated that the motion of the sides of the box to an extent of $\frac{1}{200}$ inch causes the index to move through 3 inches as marked on the dial. Watkins has invented an ingenious modification of the aneroid, by which a very considerably extended scale is afforded on a dial of some 5 inches in diameter. The pointer is drawn inwards towards the centre, with diminished pressure, and works on a scale engraved in spiral fashion, commencing with 31 inches at the outer margin of the dial, and ending with 27 inches near the centre; thus, an inch of mercury is here magnified to about 8 inches of scale, so that differences of level of 15 or 20

feet can be plainly distinguished, and the variations of atmospheric pressure in a squall of wind noted easily from minute to minute.

Aneroids are very sensitive and convenient, but liable at times to go hopelessly wrong, on which account they need to be periodically checked against a standard mercurial barometer. By a combination of a series of aneroid vacuum boxes, the movements of which by a lever are multiplied and recorded upon a revolving cylinder, so-called recording barometers have been made, and for observatory work serve a useful purpose, but are not absolutely accurate without being constantly checked against standard instruments.

Reading of Barometers.—The cases and scales of all good barometers are made of brass, because the coefficient of its expansion by heat is well known. These instruments should be hung perfectly vertical, not exposed to direct rays of the sun, or to artificial heat, and not exposed to accidental injury. An attached thermometer is always required to note the temperature at the time of taking the barometrical observation.

In all standard barometers there are in reality two scales: a principal or fixed scale, and a secondary or small movable scale, called a "vernier," which ensures greater accuracy in the reading. Each long line on the fixed scale is 0·1 inch, each short line is 0·05 inch. The vernier scale is so graduated that twenty-five of its divisions correspond to twenty-four of the half-tenth or 0·05 inch divisions on the fixed scale. Consequently, each division on the vernier is $\frac{1}{25}$th less than a half-tenth division on the fixed scale; and the vernier exhibits differences of $\frac{1}{25}$ of 0·05 inch, or $0·04 \times 0·05 = 0·002$ inch.

In taking the reading of a barometer, the first thing to do is to note the temperature of the instrument by means of the usually attached thermometer; next, adjust the mercury in the cistern to the fiducial point, if it be one made on Fortin's principle; then place the vernier so that its lowest edge is level with the top of the mercurial column, forming a tangent, as it were, to the mercurial meniscus. If the top of the mercury coincide exactly with one of the divisions on the principal scale, there is no need to use the vernier; but if it do not so coincide, the use of the vernier will accurately measure the excess of the mercury over the next lowest division on the scale. To do this, we must follow the vernier scale up, until we find one of its marks exactly corresponding with one on the fixed scale; call it x, and, as each of these represents 0·002 inch, we have $x \times 0·002$ inch as the exact distance which the mercury column is over and above the next lowest mark to it on the principal scale. Thus, in example A (Fig. 174), we find that the top of the mercury is just above 29·60 inches, but below 29·65; that is to say, neither of those readings gives the absolutely correct height of the mercury. Following up the vernier, we find that its eighth line or mark is the first to exactly coincide with one on the principal scale; therefore, if we read that as meaning eight five-hundredths of an inch, or $8 \times 0·002 = 0·016$ inch, or the exact amount by which the top of the mercury column exceeds 29·60 on the fixed scale, we get, by the addition of these two numbers, 29·616 inches as the correct reading of this particular example. In the same way, example B reads 29·058 inches.

Corrections for the Barometer.—The reading having been thus accurately taken, it remains to apply certain corrections; these are (1) for capillarity, (2) index error, (3) for temperature, (4) for height above sea-level. The first two corrections are constant, and have to do with the actual instrument. *Correction for Capillarity* depends on the size of the bore, and whether the mercury has been boiled in the tube or not. *Index Error*

is determined by comparison with a standard instrument. The capillarity and index errors are usually put together. The capillarity error is always additive; the index error may be subtractive or additive, but the two together form a constant quantity, and the certificates furnished by the Kew Observatory for the instruments verified there, and by most of the makers, include both corrections above-mentioned. *Corrections for Temperature.*—The error due to temperature is one which affects not only the mercury but also the brass of the scale, and in extremes of heat or cold may be considerable; this explains why it is so important to note the temperature before taking the reading. To secure uniformity of barometric records all nations have agreed to reduce their barometer readings to what they would have been had both the mercury and brass scale been at 32° F., or 0° C. All good barometers are made with brass scales, and for these the necessary temperature corrections are given in the following Table:—

Temp.	27 inches.	28 inches.	29 inches.	30 inches.	31 inches.
30°	−0·004	−0·004	−0·004	−0·004	−0·004
40°	−0·028	−0·029	−0·030	−0·031	−0·032
50°	−0·052	−0·054	−0·056	−0·058	−0·060
60°	−0·076	−0·079	−0·082	−0·085	−0·087
70°	−0·100	−0·104	−0·108	−0·111	−0·115
80°	−0·124	−0·129	−0·133	−0·138	−0·143
90°	−0·148	−0·153	−0·159	−0·164	−0·170
100°	−0·172	−0·178	−0·184	−0·191	−0·197

As mercury expands $\frac{1}{9990}$ of its bulk for each degree F., (1) multiply the number of degrees *above* 32° by the observed height, and divide by 9990: subtract this quotient from the observed height; or (2) multiply the number of degrees *below* 32° by the observed height, and divide by 9990: add this to the observed height.

Correction for Height above Sea-level.—As the mercury falls about $\frac{1}{1000}$ inch for every foot of ascent, this amount multiplied by the number of feet ascended must be added to the reading, if the place be above sea-level. For the British Isles, the mean sea-level at Liverpool has been selected by the Ordnance Survey as their datum. In places which are below sea-level, this correction will necessarily be subtractive, but such localities are few. If great accuracy is required, two disturbing elements must be taken into account: these are, the temperature of the air and the actual air pressure at sea-level at the time of observation.

Measurement of Heights.—The barometer falls when heights are ascended, as a certain weight of air is left below it. The diminution is not uniform, for the higher the ascent the less weighty the air, and a greater and greater height must be ascended to depress the barometer 1 inch.

A great number of methods and rules for calculating heights, from the difference in barometric readings of any two places, have from time to time been suggested; and, by means of aneroids, are not difficult to carry out. A very simple rule for approximate determinations has been given by Strachan. Read the aneroid to the nearest hundredth of an inch; subtract the upper reading from the lower, leaving out or neglecting the decimal point, multiply the difference by 9, the product is the elevation in feet.

Observations of this kind have been much facilitated by the introduction of aneroids on which altitude scales are graduated, combined with an adjustable scale for temperature. The adjustment for the temperature of the air is applied by shifting the scale in accordance with the figures engraved

on the outside of the instrument. The rim which holds the glass should be slightly raised, so as to be free from the locking-pin, and then turned until the figures corresponding to the air temperature are opposite to the pin, when the glass should be depressed so as to re-lock it. The making of an observation is simple. First determine, either by observation or by estimation, the air temperature likely to prevail during the observations; if this is done within 5° it will be sufficiently accurate. The scale must then be set to this temperature in the manner explained. The barometric readings at each place must be taken from the outer scale of feet, and the *difference* will give the difference of height between the two stations. The accuracy of the result will be increased if the observations are repeated more than once, and the average of the results taken.

Barometric Fluctuations.—Atmospheric pressure, as measured by the barometer, is subject to two classes of variation; the one is regular, the other is irregular. The regular or periodic variations are *diurnal* and *annual*, while the irregular or non-periodic variations are *cyclonic* and *anticyclonic*.

Barometric pressure will be low:—(1) When the air is heated. (2) When the air is damp; because, when watery vapour mixes with dry air, the volume of the latter is increased, with the result that a volume of air which at 50° F., when dry, measures 1 cubic foot and weighs 546·8 grains becomes, when saturated with moisture at the same temperature, 1·0121 cubic feet, with a weight of 550·9 grains; in other words, 1 cubic foot of the saturated air weighs but 544·5 grains or 2·3 grains lighter than it did when dry. (3) When the air from any cause has an upward movement, as in some varieties of wind.

Barometric pressure will be high:—(1) When the air is very cold, and consequently dense. (2) When the air is dry. (3) When in any way an upper current sets in towards a given area, thereby compressing the strata beneath.

Accordingly we find an area of low pressure in winter in high latitudes over the North Atlantic and Pacific Oceans, where the temperature is abnormally high. Conversely, the regions of highest barometrical readings are situated over the continents, in high latitudes, and in localities characterised by abnormally low temperatures.

Diurnal variations are best marked in the tropics, where the range of pressure often exceeds 0·1 inch. There are two maxima and two minima; the first maximum is about 9 A.M., the second about 10 P.M. Condensation of the air after a cold night partly accounts for the forenoon rise, coupled with rapid evaporation, and consequently increasing tension of aqueous vapour. The evening maximum is partly due to a quick fall in temperature causing condensation, and possibly also to a saturated state of the air after the evaporation of the day. The first minimum is about 3 to 4 P.M., the second at 4 A.M. The first is mainly explained by the heating and expansion of the air at the hottest part of the day; the second is probably due to desiccation of the atmosphere resulting from condensation of, and withdrawal of tension of aqueous vapour by the nightly fall of temperature.

In this country the diurnal range is less, rarely exceeding 0·02 inch, but the maxima and minima occur about the same hours as in the tropics, and are probably dependent upon similar causes supplemented by constant shifting of the wind. In these islands the barometer falls usually with the south-west winds, and rises with the north and east; the former are moist and warm, the latter dry and cold winds.

Annual variations in atmospheric pressure are on a far larger scale than the daily ranges. In so far as concerns the dry air of the atmosphere, barometric pressure might be expected to be least in the summer and greatest in the winter of each hemisphere. But the production of aqueous vapour by evaporation being most active in summer, the pressure from its tension will be increased from this cause. As the aqueous vapour is transferred to the colder hemisphere, it is condensed into rain, and being thereby withdrawn from the atmosphere, atmospheric pressure is lessened; but the dry air which the vapour brings with it from the warm hemisphere remains, thus tending to increase the pressure. In the neighbourhood of the equator, where temperature and moisture differ little in the course of the year, the variation in the mean pressure from month to month is small.

In Calcutta the average pressure in July is 29·538, and in January 30·022 inches, thus showing a difference of 0·484 inch. This large annual variation is caused jointly by the great heat in July, and by the heavy rains accompanying the south-west monsoon; while in January the barometer is high, owing to the north-east monsoon, by which the dry, cold, dense air of the continent is carried southward over India.

At places where the amount of vapour in the air varies little from month to month, but the variations of temperature are great, the annual variations of pressure are very striking. Thus, at Irkutsk in Siberia the pressure in July is 28·192 inches and in January 28·777 inches, the difference being nearly 0·6 inch. The great heat of Siberia during summer causes the air to expand and flow away in all directions, and the diminished pressure is not compensated for by any great increase of aqueous vapour tension. On the other hand, the great cold and small rainfall of that region during winter cause high pressures to prevail during that season.

In Iceland, the Orkney Islands, and in some parts of this country, the distribution of pressure is just the reverse of what obtains in Siberia, being least in winter and greatest in summer. The low winter pressures are due to the comparatively high winter temperatures causing an outflow towards adjoining countries, and to the large amount of moisture in the air, and the heavy rainfall which, by setting free the latent heat, still further augments and accelerates the outflow by the upper currents. The annual variation of pressure in the United Kingdom is most variable, but the maximum readings are usually about the end of May or early in June, while the minima are at the end of October or early in November.

Those irregular variations of barometric pressure which daily, monthly, and yearly occasion changes in wind and weather over more or less extensive areas of the earth's surface are broadly divided into the *cyclonic* and the *anticyclonic*, according as to whether they are associated with bad or good weather. In former years the value of the barometric reading was necessarily limited to the particular spot at which it was noted; but recently, as the result of increased facilities of communication between one place and another, it is possible to obtain simultaneous readings of the barometer at any given time at several places distributed over a wide area. Now, if these are recorded on a map, and lines be drawn between and connecting all places where the same pressure prevails, we obtain what is called a *synoptic chart*, made up of lines of equal barometric pressure, or *isobars*, as they are termed. This is what is actually done in all the chief meteorological stations, and experience has shown that these isobars commonly assume certain typical forms or shapes, which are again usually associated with certain kinds of weather. It is upon these data and facts that the modern methods of weather forecasting are based.

Isobars are drawn for each tenth of an inch, and tend to assume two primary and five secondary shapes (Fig. 175). If they enclose an area of low pressure, forming a circle or an oval, they are described as cyclones. If, on the contrary, the isobars encircle an area of high pressure, they are described as anticyclones. These constitute the two primary types of isobars. The secondary shapes are five in number, being for the most part modifications of the primary types, or connected with either one or other of them ; they are secondary cyclones, V-shaped depressions, wedges of high pressure, cols and straight isobars. The closeness of the isobars one to another, or the rapidity of changes of pressure, constitute what is called the " barometric gradient " ; and just as we measure and express a railway gradient as being 1 in 20, 1 in 100, and so on, so can we say that barometric gradients are so many thousandths of an inch in fifteen miles, or so many millimetres in one degree of the meridian. The steepness of the barometric gradients directly governs the velocity of the wind over any particular place, the wind's velocity being greatest at the localities of steepest gradient and *vice versa.* In addition to

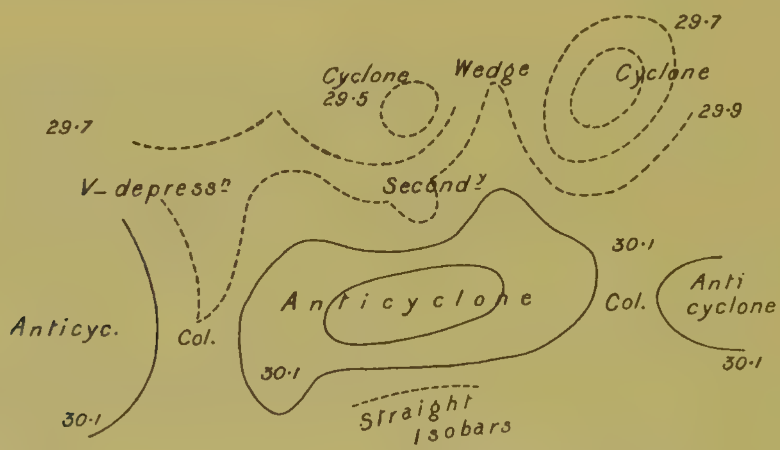


FIG. 175.—TYPES OF ISOBARS.

this, if the wind's direction at each place be noted on a synoptic chart, it is found to be nearly parallel to the trend of the isobars, and tends to cross from the higher to the lower ones. This fact has found expression in what is known as Buys Ballot's law, namely, *that if you stand with your back to the wind, the lowest pressure lies to your left and in front.*

Cyclones.—An area of low pressure, and the whole system connected with it, is called a depression or cyclone, and in America " a low." As seen on a synoptic chart, cyclones are circles formed by concentric isobars, in which the outer lines mark a higher pressure than the inner ones ; they constitute the most frequent arrangement of isobars in these latitudes. They usually travel from west to east, at the rate of about twenty miles an hour, and are invariably associated with bad weather. The *intensity* of a cyclone depends less upon the actual pressure or height of the barometer than upon the fact that the isobars are close together, and that the system is deep and moving quickly. The forces involved are due to the gradients or differences to pressure, and are greater the steeper the gradients. Hence a cyclone may be of a mild type, or be a gale or hurricane, according as to whether the gradients are gentle or steep. If we analyse the weather associated with a cyclonic disturbance, we find that the foremost portion of a cyclone area is always marked by stratiform clouds, moist heavy atmosphere, and the usual signs of coming rain, such as a pale moon, watery sun, dirty gloomy sky. As the cyclone advances, a drizzling gradually changes into a

driving rain, accompanied in the trough or situation of lowest pressure by squalls of wind. As the cyclone area shifts its position or moves onward, the rain moderates into showers, followed by a brighter sky with cumulus clouds and a sharp, brisk feeling in the air. If we study the barometer changes at different points in the path of a cyclone, it is at once obvious that in the fore part of the area of depression the barometer is everywhere falling, while in the rear part it is everywhere rising, and the turning-point, or line of lowest pressure, is what is called the trough. A cyclone may be compared to a cup-shaped hollow, the isobars being simply contour lines. The extent or area of a cyclonic disturbance may vary from ten or twenty to some thousands of miles, covering even the whole Atlantic or the greater part of Europe. Cyclones are usually oval and not circular in form, their longer diameter being in these latitudes in a direction nearly W.S.W. to E.N.E. in the majority of cases. When the dimensions become great, especially if the system be much elongated, a cyclone frequently breaks up into two, three, or even more separate centres of depression. Large cyclones are, of course, much modified in both form and position by the variations of the deflecting force due to the rotation of the earth, and arising from difference of latitude. As a rule, the higher the latitude, the greater is the average size of cyclones. In the tropics, cyclones are usually smaller and circular. It is important, however, not to confound small cyclones with either waterspouts or tornadoes, which are too small to be much influenced by the rotation of the earth, besides which they are special phenomena of a distinct nature. The direction of the wind is, in all cyclones, obliquely across the isobars, and may be described as blowing spirally into the area of low pressure towards the centre, and from the central area in an upward direction. The particular angle at which the incurving of the wind takes place in a cyclone depends on the friction between the air currents and the earth's surface, the angle being smaller the greater the friction. Thus, according to Ley, the angle between the direction of the wind and the isobars is 29° for coast stations, and 13° for inland stations, thus showing distinctly the increased effects of friction on land. It has already been stated that cyclones in these latitudes for the most part move in an easterly direction; when a westward motion occurs, it is usually slow and seldom long-continued. The advance of a depression is commonly in a direction perpendicular to the line of steepest gradient, so that the highest pressure lies to the right; while also the temperature is highest to the right of its track. The rate of advance of a cyclone varies within very wide limits; on the whole, deep depressions move faster than shallow. The average rate of motion or translation of cyclones over Europe is from twenty to thirty miles an hour, while in America they travel commonly as rapidly as fifty miles an hour. So far as is known, cyclonic storms and weather seldom or never originate within five degrees of the equator, but this intermediate tropical belt is the scene of extremely violent hurricanes, which have a tendency to move in a westerly or north-westerly direction, and, moreover, appear to behave according to laws too complex to be given in detail here.

Secondary Cyclones are areas of low pressure formed by looped or incomplete circular concentric isobars with the lowest pressure in the centre. They have many weather features in common with primary cyclones, moving like them mostly from west to east. They frequently follow primary cyclones, and their bad weather is usually associated with calm and stationary barometers.

V-shaped Depressions are angular intervals or areas with the lowest pressure in the interior, and frequently form between adjoining

anticyclones, and are, as it were, a specialised form of cyclone, or even may form part of a cyclone. They have been aptly described as tongues of depression projecting from a cyclone situated to one side; in the northern hemisphere the point or tip is usually towards the south. The wind follows the universal law of gradients, being from south to south-west in front, and from west to north-west in rear of the trough. This latter line is given at once by adjoining the southern points of each successive isobar, and in practice is nearly always curved, the convexity being turned towards the east. As the V is usually moving towards the east, this trough line marks out the position of all the places at which the barometer, having fallen more or less, has just turned to rise. The weather experienced by an observer over whom one of these areas of depression drifts is from blue sky to cloud, later on rain with a falling barometer and south-west wind, then a squall, during which the wind jumps round to north-west, followed by a rapidly clearing sky and a rising barometer. Not only secondary cyclones but V-shaped depressions are in general most uncertain in their movements, and their occurrence is consequently very difficult to foretell. The extreme rapidity with

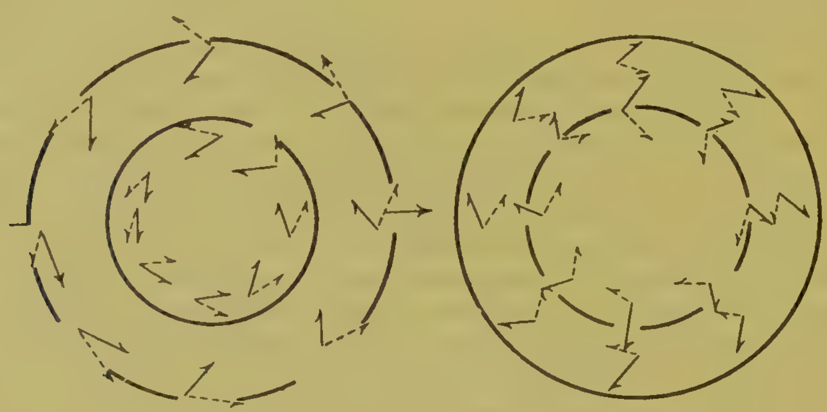


Fig. 176.—Direction of Wind Currents in Cyclone and Anticyclone.

which they travel at times, and the violence of the wind and rain developed within them, render them a source of great danger to both life and property. The peculiar thunderstorms of Central Europe and America are nearly always associated with V-shaped depressions.

Anticyclones.—These are areas of high pressure formed by more or less circular isobars, with the highest pressure in the centre. They differ from all other arrangements of isobars in tending to remain stationary and, also, to extend over large areas. The air is calm and cold in the centre, while on the borders the wind blows round the centre spirally outwards in the direction of the hands of the clock; thus on the east side the wind comes from the north, on the south from the north-east, on the west from the south-east, and on the north from the west. In describing the cyclonic system it was explained how the wind in the centre of that system was an ascending current; that wind circulation is compensated by an equivalent descending current in what is in all respects the opposite of a cyclone, namely, the anticyclone. The characteristic circulation of the air in this is, therefore, exactly the reverse of that in a cyclone: it blows in the same direction as the hands of the clock move, spirally outwards from the centre at or near the surface of the earth, and inwards towards the centre at the level of the highest clouds. In Fig. 176 we give a diagram of the highest and surface currents in both a cyclone and an anticyclone; the solid arrows denote the

surface winds, while the highest currents are given by the dotted arrows. In anticyclonic systems the barometric gradients are slight, and the normal wind circulation usually disturbed or disguised by accidental or local causes. The general weather features of an anticyclone are the exact opposite of cyclonic conditions, being in summer characterised by dry, quiet, bright weather, hot suns by day being followed by cool nights, except in the north-west quadrant of the system, where the nights are warm and often cloudy. Sea fogs are prevalent when the calm-centre overlies the sea ; and in most cases much haze obscures the horizon. In winter, however, dense fogs sometimes accompany the calms of an anticyclone, and in parts of its periphery the sky may be densely clouded. If rain should fall, it is usually drizzling, not heavy. During winter, intense cold prevails in the centre and in the south-east and south-west quadrants of the area ; in the north-east and north-west quadrants, at least in Western Europe, conditions are milder. Certain regions of the globe are remarkable for the existence of permanent and recurrent anti-cyclone systems. There is a permanent area of high pressure near latitude 30° north, called the Atlantic anticyclone, which varies in extent from month to month, attaining its greatest intensity in summer and least in winter. Another permanent area is that over the large land surface of Asia and Eastern Europe, in which the pressure is usually excessive during winter. It is the existence and more or less permanency of these two large areas of high pressure which combine to give a north-westerly gradient towards a stationary low pressure centre near Iceland, and to govern the motions of cyclones, which tend to skirt round their borders in an easterly direction. It is important to remember that, while an anticyclone system compensates a cyclone in the matter of transferring air from one level to another, there is no mutual relation between them in the sense of cause and effect.

Wedge-shaped Isobars usually point to the north in this hemisphere and indicate areas of high pressure moving along between two adjacent cyclones. Though very usually associated with fine weather, it is only temporary, because wedges of high pressure are never stationary, and are commonly followe ! by well-defined cyclonic areas. So far as weather is concerned, we may regard the two sides of the wedge as the rear and front of cyclones, and the wedge itself as a mere projecting tongue of an anticyclone. The wide end of the wedge is often associated with fog, and the narrow end with thunderstorms or showers.

Cols, or necks of comparatively low pressure, generally lie between two anticyclonic areas. Over them the weather is dull, gloomy, and stagnant, while in summer violent thunderstorms are frequently associated with them. Like the following, cols are essentially intermediate systems.

Straight Isobars are those without any curve, and may trend in any direction. This arrangement of isobars only marks the position of a barometric slope, and does not enclose any area of either high or low pressure. This form is essentially temporary and an intermediate arrangement of the atmospheric circulation or pressure which precedes the formation of a cyclone. The weather associated with straight isobars is too transitional to be characteristic, but very frequently is that of a hard sky, with a blustering wind and an inclination to rain.

What are known as squalls, or puffs of wind of varying intensity, appear to be caused by the sudden breaking of the cold dense upper layers of air through lower and warmer layers lying underneath, condensing the vapour in the latter and causing them to ascend. In contrast to them are the various kinds of squall attributable to the sudden ascent of masses of warm

air; examples of this phenomenon we know, as the familiar dust whirls on a dry road, or the dust storms, waterspouts, and tornadoes of the tropics. As in the case of cyclones and anticyclones, the question, What is the cause of these descending and ascending air currents? is one of some complexity, and has not yet received an adequate explanation.

It must not be forgotten that all the foregoing forms of isobars are at any time liable to break up, or at least to pass into new forms, so that, although every part of every shape of isobars has a characteristic weather and sky appearance, still, owing to their often rapid breaking up, forecasting of weather is not always certain to come true. Cyclonic disturbances, for instance, are frequently diverted from their course by meeting a coast-line or range of mountains, or even by the formation of areas of high pressure; so that their velocity is neither regular nor their direction of movement necessarily straight. On the other hand, experience shows that when advantage is taken of transatlantic and other meteorological observations telegraphed to a central meteorological office, synoptic charts can be prepared of such magnitude and detail as to render weather forecasting comparatively successful in a great percentage of cases. All meteorological phenomena are practically the products or results of the circulation or motion of a moist atmosphere, and consequently forecasting weather is nothing more than saying how and where certain air currents or eddies will move, or when new ones will form, and whether they will be gentle or violent. From the rapidity with which meteorological changes take place, the use of telegraphy is absolutely necessary if any success is to be attained in forecasting, and even this information can be only of use in some central office presided over by an experienced forecaster thoroughly conversant with the motions of low-pressure areas in his own country. It will be readily understood that in some countries forecasting is easier than in others. Thus, in the temperate zone, where most disturbances move from the west, those countries will be best suited for weather forecasting which lie to the east of a well-observed land area. For this reason Norway and Germany are better placed for weather forecasting than either France or England. Large areas of land and water mainly determine the great areas of high and low pressure, hence Great Britain being placed on the boundary, so to speak, between anticyclonic and cyclonic systems, renders the prognostication of weather peculiarly difficult in these islands, more particularly as their geographical position precludes an early knowledge of cyclones forming over the Atlantic. Moreover, just as an outlying rock is exposed to the wash of every sea, so is England exposed to the disturbing influences of every type of European or Atlantic weather, and has, in consequence, more unsettled weather than any other part of Europe.

Notation of Charts.—In order to simplify and condense as far as possible the notes placed on synoptic charts and meteorological returns, it is convenient to have a notation or uniform system of abbreviations. The one usually adopted is that given below.

Wind is represented by an arrow flying with it, thus:—↑ means S., → means W., ↓ means N., ← means E., and so on. The force of the wind is indicated by the number of barbs or feathers on the arrow, thus:—∧ light breeze; ↑ fresh breeze; ↟ strong wind; ↟ a gale; and ⊙ signifies calm.

Temperature and *Moisture*, being usually given as numerical results of instrumental observations, are omitted for the present. The remaining elements which go to make weather are described by letters and symbols as follows, a bar or dot under a letter denoting intensity.

b = blue sky: whether with clear or hazy atmosphere.
c = cloudy, but detached opening clouds.
d = drizzling rain.
f = foggy, ≋
g = dark gloomy weather.
h = hail, ▲
l = lightning, <.
m = misty hazy atmosphere, ≋ or ∞.
o = overcast, the whole sky being covered with an impervious cloud.
p = passing temporary showers.
q = squally.
r = rain, continued rain, ●.
s = snow, ✱.
t = thunder, T.
u = "ugly," threatening appearance of the weather.
v = "visibility" of distant objects, whether the sky be cloudy or not.
w = dew, ⩡.

The above notation, devised by Admiral Beaufort, has long been in universal use in this country. The following symbols have been added more recently, and are officially recognised by the various European meteorological institutions:—

Thunderstorm . . .	Ꝁ	Strong Wind, . . .	⚑
Soft Hail ("Graupel"), . .	△	Solar Corona, . . .	⊙
Hoar Frost, ...	⊔	,, Halo, ...	⊕
Silver-thaw ("Rauh-frost," "Duft"), ...	V	Lunar Corona, . . .	Ѡ
		,, Halo, ...	Ⓦ
Glazed Frost ("Glatteis"), .	~	Rainbow, ...	⌒
Snow Drift, ...	✢	Aurora, ...	♕
Ice Crystals, ...	←	Dust-haze ("Höhen-rauch"),	∞

In these symbols intensity is to be indicated by the exponents 0 and 2 attached to the symbols, thus:—

$\ast^0$ means slight snow. $\ast^2$ heavy snow.

CHAPTER XX

RECENT SANITARY LEGISLATION

Since the greater part of the preceding pages have been in print, certain Acts of Parliament have been passed which modify some of the sanitary legislation explained in this book. The precise bearing of this recent legislation will be understood by a study of the following summary.

Food.—The Public Health (Regulations as to Food) Act, 1907, enables a Sanitary Authority to make regulations for the prevention of danger arising to public health from the importation, preparation, storage, and distribution of articles of food, in amplification of the power which such authority possesses under the Public Health Act, 1896. For the purposes of regulations under this Act, articles commonly used for food or drink by man shall be deemed to be intended for sale for human consumption unless the contrary be proved. In the application of this Act to Scotland, Part IV. of the Public Health (Scotland) Act, 1897, shall be substituted for the Public Health Act, 1896.

All regulations made under this Act must be laid before Parliament, and the Rules Publication Act, 1893, shall apply to such regulations as if they were statutory rules within the meaning of section 1 of that Act. In its application to Scotland, the regulations must be published in the *Edinburgh Gazette*.

Butter and Margarine.—An Act to make further provision with respect to the manufacture, importation, and sale of butter and margarine and similar substances comes into operation on January 1, 1908, entitled the Butter and Margarine Act, 1907. The provisions of section 9 of the Margarine Act, 1887, as amended by section 7 of the Sale of Food and Drugs Act, 1899, relating to the registration of manufactories of margarine are made by this Act of 1907 to apply to butter factories and to any premises on which there is manufactured any milk-blended butter. Similarly, the provisions of section 7 of the Sale of Food and Drugs Act, 1899, relating to consignments of margarine, apply to consignments of milk-blended butter (section 1). Premises may not be used as butter factories if they form part of other premises which are required to be registered under the Sale of Food and Drugs Act. This does not apply to premises which were being used as a butter factory on January 1, 1907.

Officers of the Board of Agriculture and Local Government Board have power to enter at all reasonable times any premises registered either under this Act or the Sale of Food and Drugs Acts (section 2). Sub-section 2 of section 7 of the Sale of Food and Drugs Act, 1899, is repealed. It is an offence under this Act for any substance for the adulteration of butter to be found in any butter factory.

By section 4 of this Act of 1907, it is an offence to manufacture, sell, or expose for sale or consignment, butter or margarine containing more than 16 per cent. of water, or any milk-blended butter containing more than 24 per cent. of water. By section 5, it is illegal under section 1 of the Sale of

Food and Drugs Act, 1899, to import butter or margarine or milk-blended butter not conforming to these requirements, or to contain a preservative prohibited by any regulation made under this Act. In any proceedings under these sections, the certificate of the principal chemist of the Government Laboratories shall raise a presumption, until the contrary is proved, that an imported substance is margarine or milk-blended butter. The power of making regulations under section 4 of the Sale of Food and Drugs Act, 1899, shall extend to making regulations as to preservatives in butter, margarine, or milk-blended butter, and to the proportion of any milk-solid other than milk-fat in butter or milk-blended butter.

In the marking of wrappers or labels, margarine must be described either as margarine, or by a name combining the word "margarine" with a fancy or descriptive name. Any fancy or descriptive names for margarine preparations must be approved by the Board of Agriculture and printed in the same size of type and colour as the word margarine. Milk-blended butter must be dealt with under such name or names as may be approved by the Board of Agriculture and under the same conditions as those relating to margarine, with this modification, that in addition to any approved name, the wrapper or label must set out the percentage of water contained therein and approved by the Board. Section 8 of the Margarine Act, 1887, applies to milk-blended butter as well as to margarine (sections 8 and 9).

For the purposes of the Sale of Food and Drugs Act and this Act of 1907, the expression "margarine" means any article of food, whether mixed with butter or not, which resembles butter and is not milk-blended butter (section 13). This definition replaces that given in the Margarine Act, 1887. Except in the Administrative County of London, inspectors of weights and measures have power to take samples of butter or margarine under section 8 of the Act of 1887. This Act of 1907 must be construed as one with the Sale of Food and Drugs Act, 1899.

Schools.—By the Education (Administrative Provisions) Act, 1907, which comes into operation on January 1, 1908, the powers and duties of a Local Education Authority under Part III. of the Education Act, 1902, shall include the provision of vacation schools, play centres, as well as the medical inspection of children immediately before, or at the time of, or as soon as possible after, their admission to a public elementary school, and on such other occasions as the Board of Education direct. They have, further, powers to make other arrangements for the improvement of the health and physical condition of the children attending public elementary schools. These powers are subject to sanction by the Board of Education, but constitute a notable advance in respect of the relations of the Local Authority to elementary education.

Streets and Buildings.—By Part II. of an adoptive Act called the Public Health Acts Amendment Act, 1907, coming into operation on January 1, 1908, certain changes are made in regard to the law concerning streets and buildings. By section 15, any deposited plan will be of no effect if the work is not commenced within three years from the date of deposit; and all plans deposited are to remain the property of the authority. Section 17 gives the Local Authority power to vary the position or direction and fix the beginning and end of new streets. Further, in the case of private streets, the authority has power to call upon owners of land or premises abutting thereon to "obviate or remove dangers." Sub-section 4 of section 19 gives a majority in number or rateable value of owners in a private street power to require the Local Authority to make up the street under section 150 of the Public Health Act, 1875, and adopt it as a public highway.

Clause 24 of this Act of 1907 extends section 157 of the Public Health Act, 1875, so as to empower the Local Authority to make bye-laws with respect to the height of chimneys and also the height of buildings. Similarly, power is given to compel paving of yards, to prevent the closing or narrowing of entrances to courts, and to control the erection of temporary buildings (sections 25, 26 and 27). Local Authorities have also power to remove, appropriate, use and dispose of old building material in streets, while it is made unlawful to make excavations on or in any streets without consent (sections 28 and 29). Provision is also made in regard to the repairing, enclosing or fencing-in dangerous places and lands adjoining public streets (sections 30 and 31). Any hoardings abutting on to or adjoining any street shall be fixed to the satisfaction of the Local Authority.

Drainage and Sewerage.—The first section (33) of Part III. of the Public Health Acts Amendment Act, 1907, varies section 41 in the Public Health Act, 1875, by enabling the Local Authority to enter into a house for the purpose of inspection on the report of one of its officers, and not solely on the written application of some " person " as heretofore. The responsible officer can now enter where he has reason to suspect that any drain, water-closet, earth-closet, privy, ashpit or cesspool is a nuisance or injurious to health. For the purposes of the Act of 1875, the nuisances are amplified and include cisterns, gutters, drains, shoots, stack-pipes and deposits of material in or on any building or land which shall cause damp in such building (section 35). Rain-water pipes may not be used as soil-pipes or as ventilating shafts (sections 36 and 37). By section 38, any old drain intended to be connected up with a public sewer must be laid open for examination by the surveyor.

An important section in this Act of 1907 is number 39, which gives a Local Authority power to order such number of closets in a domestic building as they shall deem necessary to the size of such building. For the purposes of this section, the provisions of sections 102 and 103 of the 1875 Act apply to the powers of entry on premises. By sections 43 and 44, the Local Authority has power to deal with any urinal or sanitary convenience opening on to a public street, also to insist on the provision of urinals in public-houses, or places of refreshment or entertainment. Section 45 authorises the Local Authority, on the report of one of its responsible officers, to apply the smoke or coloured water test (not including a test by water under pressure) to drains, but the consent of the owner or occupier must be given, or an order of a Court of Summary Jurisdiction must be obtained. Should any defects be found, the Local Authority can compel repairs to be made. Similar powers are given to deal with and fill up cesspools or other receptacles for obnoxious matter, if reported by a responsible officer of the authority as being prejudicial to health or objectionable for sanitary reasons. Section 49 empowers a Local Authority to give notice to provide sinks and drains or other necessary appliances for carrying off refuse water, to all buildings built before or after the passing of the Act.

Common Lodging-houses.—The Public Health Acts Amendment Act, 1907, gives discretion to the Local Authority to refuse registration of a common lodging-house keeper, notwithstanding the production of a certificate signed by three ratepayers (section 69). The following two sections entail an obligation on a common lodging-house keeper or his deputy to provide for proper control of his house. Further, the Local Authority must keep a register of deputies, and if at any time it is of opinion that such registered deputy is not a fit person for the purpose, may cancel the registration. The registration of keepers of common lodging-houses

shall remain in force only for a year, but may be renewed from time to time by the Local Authority.

A Court convicting a common lodging-house keeper of any offence against the provisions of the Public Health Acts, has power to cancel registration (section 72). Unregistered lodging-house keepers are liable to penalties imposed under section 86 of the Public Health Act, 1875, for the offences named therein. Every common lodging-house, whether registered before or after the commencement of the Public Health Acts Amendment Act, 1907, must be provided with proper sanitary conveniences to the satisfaction of the Local Authority (section 74).

Offensive Businesses.—By section 51 of the Public Health Acts Amendment Act, 1907, the power of a Local Authority to declare a business to be an offensive business is extended by the substitution of the words "any other trade, business, or manufacture, which the Local Authority declare by Order confirmed by the Local Government Board, and published in such manner as the Board direct, to be an offensive trade" for the words "any other noxious or offensive trade, business or manufacture" in section 112 of the Public Health Act, 1875. Moreover, a Local Authority may make bye-laws with respect to any trade which is declared by it to be an offensive trade under section 112 of the Act of 1875 as amended above by the Act of 1907.

Infectious Diseases.—Where the Public Health Acts Amendment Act, 1907, is adopted, the powers of Local Authorities to deal with the infective diseases are materially strengthened. By section 52 of this Act, if any person knows that he is suffering from an infectious disease he shall not carry on any trade or occupation unless he can do so without risk of spreading the infectious disease. The penalty in respect of each offence is forty shillings. Further, if the Medical Officer of Health suspects that any case of infectious disease is attributable to the milk-supply, the Local Authority can call upon the dairyman supplying the milk to furnish a list of places from which he derives such supply. Payment for these lists to be at the rate of sixpence for every twenty-five names. Failure to comply entails a fine of £5 and a running penalty not exceeding £2 per day (section 53). Dairymen are also required to notify the medical officer of any cases of infectious disease amongst their employés (section 54).

Infected clothes may not be sent to a laundry, and the Local Authority may, on application of any person, pay the expenses of the disinfection of any such clothing or bedding, if carried out by them or under their direction (section 55). Also, the authority is empowered to cleanse, purify or destroy any article in a dwelling-house which, by reason of its filthy condition, might prove dangerous to the health of any persons in the house. Reasonable compensation to owner may be given (section 56).

Children suffering from infectious disease may not attend school (section 57), and principals of schools where a scholar is suffering from an infectious disease can be called upon to furnish lists of scholars to the Local Authority; the penalty in default being a fine of forty shillings. These lists to be paid for at the rate of sixpence for twenty-five names (section 58). The borrowing of books from public or circulating libraries is illegal for persons knowing themselves to be suffering from an infectious disease (section 59).

Under section 61 of this adoptive Act of 1907, a Local Authority may exercise powers of section 15 of the Infectious Disease (Prevention) Act, 1890, whether that section has or has not been adopted in the district, and, if they so determine, can remove persons from infected premises and provide for their temporary shelter or accommodation. If any such person does

not consent to be so removed, a compulsory order from two justices can be obtained on application by the Local Authority. Penalties attach to wilful disobedience or obstruction of an order under this section. Section 126 of the Public Health Act, 1875, which imposes a penalty on the exposure of infected persons and things is amended so as to read in paragraph two as if the words " or causes or permits such sufferer to be exposed " followed after the word " sufferer " (section 62). Owners or drivers of public vehicles are prohibited from knowingly conveying infected persons in public vehicles, but if such incident come to their knowledge they must give notice to the Local Authority, who must, on request of the owner or driver of such public vehicle, disinfect the same free of charge, except in cases where the owner or driver knew that the person conveyed was suffering from infectious disease (sections 63 and 64). Full powers to cleanse and disinfect premises are given to the Local Authority on certification by their medical officer that such cleansing and disinfection is necessary to prevent or check disease. Notice to do so may be given to owner or occupier, failure to comply within twenty-four hours gives the Local Authority power to enter on any premises by day and carry the disinfection out under the superintendence of the medical officer. Reasonable compensation for damage must be given (section 66). A Local Authority may provide nursing attendance for cases of infectious disease, where removal to hospital is likely to endanger the patient's health (section 67). The holding of wakes over bodies of persons dying of infectious diseases is unlawful (section 68).

Cholera, Yellow Fever and Plague Regulations.—By their Order No. 47822 of September 9, 1907, the Local Government Board have rescinded the regulations prescribed by their Orders of November 9, 1896, and December 24, 1902, and issued new regulations as to Cholera, Yellow Fever, and Plague. These regulations are made under section 130 of the Public Health Act, 1875, as amended and extended by the Public Health (London) Act, 1891, the Public Health Act, 1896, and the corresponding Act, 1904.

The older regulations were explained on page 7 *et seq.* The new regulations have been framed so as to apply to every Port Sanitary Authority (other than those of Bristol, Gloucester, Harwich, Ipswich, Liverpool, and Manchester), as well as to every Council of a Municipal Borough or other Urban District and to every Rural District Council whose area includes or abuts on any part of a Customs Port, which part is not within the jurisdiction of a Port Sanitary Authority. The majority of the provisions contained in the new regulations are similar to those in the older, and it is not necessary to set them out in detail.

The main principles on which regulations on this matter have proceeded are that a report with regard to infected vessels arriving from foreign ports should be made by the Officers of Customs to the Port Sanitary Authority of the place on arrival; that infected vessels should be detained temporarily, pending visitation by the Medical Officer of Health of the place; and that, after visitation by the Medical Officer of Health of such vessels, or of any other vessels to which suspicion of infection attaches, the measures indicated by the regulations should be taken. Such measures have included, according to circumstances, the further detention of the vessel, the removal of persons suffering or suspected to be suffering from plague, cholera, or yellow fever, the adoption of steps to free the vessel from causes of infection, and such other action as is expedient for the purposes of tracing the further movements of persons allowed to leave the vessel. Some modifications of the regulations have now been made.

In relation to vessels arriving from foreign ports, a new classification is adopted. The term " infected ship " is limited to a ship on which there is actually on board at the time a case of cholera, yellow fever, or plague, or on which there has been a case of cholera or plague within seven days before arrival, or a case of yellow fever within eighteen days before arrival. At the same time the term " suspected ship " is used as applying to a ship on which there has been a case of cholera or plague more than seven days before the arrival of the ship, or a case of yellow fever more than eighteen days before arrival, whether the case has occurred in the port of departure or in another port in the course of the voyage, or at any time during the voyage, and on which no fresh case of cholera or plague has occurred within the seven days, or of yellow fever within the eighteen days. In this connection, it is important that Medical Officers of Health of Port Sanitary Authorities should keep themselves informed as to the ports that may be infected, and should advise the local Officers of Customs as to the ports from which it is anticipated that ships liable to detention by those officers might come, or at which they might have called.

If a ship is certified to be " infected " the regulation in Article XV. (except as regards any person actually suffering from cholera, yellow fever, or plague, or from any illness which may prove to be one or other of those diseases) prohibits the landing of any person who is on board, unless he satisfies the Medical Officer of Health as to his name, intended destination, and intended address at such place. As regards a " suspected " ship, under Articles XX. and XXI., a similar provision does not come into operation unless the Medical Officer of Health certifies that it is desirable that the provision should take effect. In either case, the permission to land is coupled with an obligation that any change of address or destination within five days after landing must be notified forthwith either to the Port Medical Officer or to the Local Authority of the district in which the place of actual destination or address is situate.

Under Article XIX. of the new regulations the measures of disinfection that may be applied to an infected or a suspected ship, as apart from articles in it, are restricted to instances in which the infection is due to cholera or plague, and they are to be confined to those parts of the ship which have been used as quarters by the person so infected, or which, in the opinion of the Medical Officer of Health, are infected with either of these diseases. The disinfection or destruction of articles on board the ship is restricted to those which may be infected with cholera or plague. Similarly, certain proceedings for dealing with bilge water, water ballast, drinking and cooking water, which under former regulations were requisite in the case of yellow fever and plague, are now made necessary only in those instances where cholera is in question.

New provisions have been made in Articles XXIII. and XXIV. for preventing the transmission of plague by rats on board ship, and the escape from the ship to the shore of rats that may be infected with plague. These are obligatory in the case of infected ships, but in the case of a suspected ship, only where the Medical Officer of Health requires them to be followed. Where a ship is neither infected nor suspected by reason of plague, but has come from, or has during the voyage called at, a port infected with plague, if the Medical Officer of Health certifies that they are necessary, the measures for destruction of rats are to be applied and the cost borne by the Sanitary Authority. The enforcement of measures for effectually stopping the access of rats from the ship to the shore is left to the discretion of the Medical Officer of Health

In view of the part now known to be taken by a certain species of mosquito in the transmission of yellow fever to man, a new provision is made in Article XXV. enabling the Medical Officer of Health to give a certificate requiring the taking of measures intended to secure the destruction of mosquitoes and their larvæ on board ship subject to the conditions set out in that article. The Sanitary Authority are obliged to do any such work as is specified at the request of, and in substitution for, the master of the ship. If they think fit, they can recover the cost of the work so done, but they may not derive any profit, and the amount recoverable may not, in relation to any piece of work, exceed £20.

Notification of Births.—A Local Authority may by resolution adopt the Notification of Births Act, 1907. This Act provides that, in the case of every child which issues forth from its mother after the expiration of the twenty-eighth week of pregnancy, whether alive or dead, it shall be the duty of the father of the child, if he is actually residing in the house, and of any person in attendance upon the mother at the time of, or within six hours after, the birth to give notice in writing of the birth to the Medical Officer of Health of the district in which the child is born. Notice of birth shall be given by posting a prepaid letter or postcard within thirty-six hours after the birth, or by delivering a written notice of the birth at the office or residence of the Medical Officer of Health. The Local Authority shall, on application, supply without charge addressed and stamped postcards containing the form of notice to any medical practitioner or midwife residing or practising in their area. Non-compliance with this Act entails a penalty of twenty shillings. This notification is in addition to and not in substitution for the requirements of the Act relating to the registration of births. The expenses incurred by a Local Authority in the execution of this Act shall, in urban districts, be paid as part of the expenses relating to public health, and in the case of a rural district council shall be paid as general expenses.

Where the Notification of Births Act, 1907, is adopted by the council of a county, the county Medical Officer of Health shall be substituted for the corresponding officer of the district. In London, the Medical Officer of Health of every Metropolitan borough, including the city, in which this Act is in force shall send weekly to the London County Council, in a form prescribed by the Local Government Board, a list of notices of births received by him under the Act during the past week. The Local Government Board may, by Order, declare this Act to be in force in the area of any Local Authority who have power to adopt the Act, although it has not been so adopted, if they think it expedient. The Act is applicable to Scotland and Ireland as well as England and Wales.

CHAPTER XXI

MILITARY HYGIENE

THE term "military hygiene" is used to signify the care of troops. The State employs a large number of men, whom it places under its own social and sanitary conditions. It removes from them much of the self-control with regard to hygienic rules which other men possess, and is therefore bound by every principle of honest and fair contract to see that these men are in no way injured by the system. But more than this : it is as much bound by its own self-interest. It has been proved over and over again that nothing is so remunerative as the outlay which augments health and, in doing so, augments the amount and value of the work done. As an army depends entirely on the physical character of the men who compose it, it is necessary briefly to refer to this part of the subject.

Selection of Recruits.—The British Army is enlisted on the voluntary system. The terms of enlistment are liable to vary according to the national requirement of the time, but at present they stand at either eight years with the colours and four in the reserve, as for the household cavalry and garrison artillery, or seven years with the colours and five years in the reserve, as for cavalry and infantry of the line, or six years each with the colours and in the reserve, as in horse and field artillery, or three years with the colours and nine in the reserve, as for engineers, the medical corps, and the army service corps. The limits of age at which recruits are taken are from eighteen to twenty-five years, while in some of the technical corps the limit may be extended to twenty-eight years. Boys, however, may be enlisted as drummers. Recruits must be of a certain height, which varies with the supply of men volunteering for military service and for different arms of the service; for the household cavalry, it is from 5 ft. 11 in. to 6 ft. 1 in.; for the cavalry of the line, from 5 ft. 6 in. to 5 ft. 9 in.; for drivers in the royal artillery, 5 ft. 2 in. to 5 ft. 6 in.; and drivers in the royal engineers, from 5 ft. 4 in. to 5 ft. 6 in., and for gunners and sappers in these two corps, 5 ft. 6 in. and upwards; for the foot guards, 5 ft. 8 in. and upwards; for the infantry of the line, 5 ft. 3 in. and upwards; and for the departmental corps, from 5 ft. 3 in. to 5 ft. 5 in. A certain minimum girth of chest is also required, and a certain minimum of weight; the chest measurement must not be less than 33 inches, nor the weight less than 115 lb. For cavalry and artillery this weight is too small; experience has shown that the minimum weight for these branches of the service should not be less than 125 lb., as this is the lowest weight that would give a cavalry soldier power at once to control his horse and wield his weapon, or a driver strength to manage a pair of horses.

Before his enlistment is completed, the recruit is carefully examined by a medical officer. The examination is a strict one and aims at investigating, as far as possible, the mental condition, the senses, the general formation of the body, the absence of infirmity or injury likely to interfere with his duties as a soldier, the condition of the heart, lungs, and abdominal organs generally,

the state of the joints, the condition of the feet, absence of hernia, varicocele, &c., and his power of vision.

The trades of the men furnishing the recruits vary greatly from year to year, labourers, servants, and husbandmen forming the larger proportion generally, and manufacturing artisans contributing the next larger number. Of the recruits examined in the United Kingdom during the year 1905, 355 per 1000 were rejected. Among the causes of rejection, the most frequent was defective development, that is, under the standard for height, chest measurement, and weight, the ratio being 73·8 per 1000; loss of teeth was the next most frequent cause, and accounted for 72·3 rejections per 1000; defective vision, heart affections, defects of the lower extremities, and diseases of the veins were among the other causes, and in the order given.

After the recruit has been enlisted and approved, he joins his depôt or his regiment; receives his kit, which he subsequently in part keeps up at his own cost; and is put on the soldier's rations. He enters at once on his drill, which occupies from three to four hours daily. Wherever gymnasia are established, he goes through a three months' course of gymnastic training for one hour every day. He next goes through a musketry course, which lasts about six weeks, and then joins the ranks. During his first year of service, he has another six weeks' gymnastic training, and is then supposed to be a finished soldier.

As regards *age*, many competent officers consider that no recruits should be enlisted under twenty to twenty-one years. This opinion is based on the fact that the most effective armies are those in which the youngest soldiers have been over twenty-two years of age. At eighteen the bones are not fully formed, nor do the muscles reach their mature growth much before twenty-five years; while thus undeveloped and immature, as they must be at eighteen years, it is useless to expect any long-continued exertion or energy from men at that age. If enlisted, the State should recognise this, and suit the work to their strength; at eighteen, recruits have not only to work, but to grow and develop, and they should have precisely the amount of exercise and kind of work best fitted for them.

As regards *vision*, the experience of the London recruiting officers is that imperfect or defective vision increases with ascent in the social scale; it is, on the whole, less perfect among the better than the lower class of recruits, and among the town-bred than among those from the country.

The importance of a due correlation of height, weight and chest measurement in estimating physique as a whole, has long been recognised; good weight for height being the first need. An easy rule is that up to 5 ft. 7 in. thrice the height in inches ought to be about the weight in pounds; adding 7 lb. for every inch above sixty-seven inches. According to Broca, the weight in kilogrammes should correspond with the number of centimetres in stature above one metre. Our experience is that a recruit's weight after a few months' service is influenced by his calling before enlistment. Men coming from a sedentary occupation, such as clerks, tailors, saddlers and so on, put on weight very quickly, whereas those who had had opportunities for overfeeding, such as bakers, brewers, butchers and confectioners, lose it with corresponding rapidity. Recruits recovering from illness, or who have had to work and live under defective sanitary conditions, may safely be accepted when below the standard, for their weight is sure to increase, and the same rule applies to youths brought up in poverty and who have not had as much food as they could eat.

The measurement of the "chest capacity" is of great importance in determining the vigour of the recruit. Experience shows that the maximum

expansion of the chest of a man of average size between eighteen and twenty-five years of age is from 2 to $2\frac{1}{2}$ inches. The method adopted for ascertaining these measurements is as follows:—On carefully adjusting the linen tape just below the point of the shoulder-blades behind and above the nipples in front, the recruit is directed to take a deep breath and expand himself to the utmost; this being done two or three times, the maximum expansion is ascertained; the minimum is found by deducting 2 to $2\frac{1}{2}$ inches according to the height and general physique of the man. The minimum and maximum are then recorded above each other, as $\frac{33}{35}$ or $\frac{34}{36\frac{1}{2}}$ as the case may be.

Seggel arrives at the conclusion that the width of the shoulder is an important measurement to make in examining soldiers. He takes the measurements with the arms hanging at the sides or held straight out in front of the body; the width of the shoulder should not be less in a properly built man than two-ninths of the man's height, the best minimum to take being one quarter of the height. The antero-posterior diameter of the chest is measured at three points—the superior border and middle of sternum and tip of ensiform cartilage. Seggel found that the greater this sagittal measurement, the greater was the chest expansion.

While the principles of water- and air-supplies for soldiers do not materially differ from those already explained for communities in general, there are certain features of military life which require special consideration; these are *barracks*, *huts*, *tents*, *equipment*, *food*, *clothing*, *work*, and life in *camps* or on *field service*. These conditions are extremely various, as the soldier serves in so many stations, but the chief points common to all can be passed in review.

THE HOUSING OF THE SOLDIER.

Barracks have been in our army, and in many armies of Europe still are, a fertile source of illness and loss of service. At all times the greatest care is necessary to counteract the injurious effects of compressing a number of persons into a restricted space. In the case of soldiers the compression has been extreme in the past, but thanks to the better recognition of sanitary principles the general housing of the soldier in the present day is fairly good. The plans on which barracks were formerly built exhibit every possible variety as regards design and internal arrangement. In many cases, the chief object in view appears to have been to place as many men as possible on the ground at disposal. Space will not permit of a review of this interesting section in military history, the most that can be attempted is a summary of the principles on which the home of the soldier should be designed.

The selection of the site is of the first importance It should be open, though not necessarily devoid of trees—fairly elevated, and freely exposed to the atmosphere, although protected from cold winds. The ground around should have a fair fall to facilitate drainage, with natural drainage outlets, a dry and porous soil, and be well removed from any undrained marshy land, stagnant water, deep ravines and nuisances generally. To those called upon to select sites for buildings or camps, the value of a visit to the locality in the evening, when conditions are favourable to fogs and mists, is a practical point worth remembering. As for soil, gravel, sand and chalk form as a rule good sites, so do limestone and sandstone. Loams, marl and clay are not satisfactory often, unless well drained. The worst soil features are shallow beds of gravel or sand overlying clay, reclaimed lands, alluvial tracts, and

generally made-up soils. As to subsoil conditions, the most important feature is that the ground water be both deep and fairly constant in level.

Following the considerations affecting the choice of a site suitable for barracks, come those which govern the disposition of these buildings on the ground. The aspect or orientation should depend on the purpose which the buildings are intended to serve and on their geographical position. Thus, in a temperate climate, we seek as much sunshine as possible, whereas, in tropical countries, we have to protect barracks and their occupants against the direct rays of the sun. For these reasons, we find barracks at home built generally with their long axis north and south and their windows facing east and west; in tropical climates, on the other hand, the comparatively horizontal rays of the morning and evening sun slanting directly into windows have to be avoided and the aspect modified accordingly. These general principles do not apply to such buildings as stores, while the existence of certain winds in hot climates or the exigencies of a site may necessitate modification of the above rules. Due consideration being given to the foregoing factors, the following notes will suffice to explain the relative positions of barrack buildings with regard to one another and to parade grounds and means of communication.

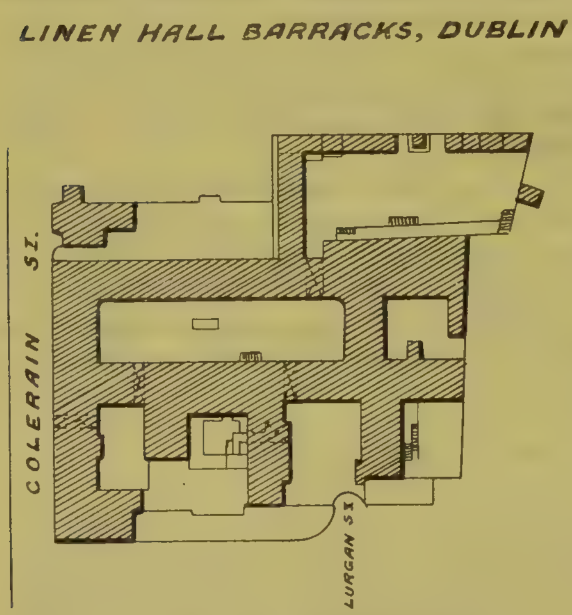


Fig. 177.—Block Plan of Obsolete Type of Barrack.

Barrack blocks should be arranged together and adjacent to the parade ground, and for mounted units convenient to stables also. Cook-houses, baths, and latrines, and dining-rooms should all be close to the barrack rooms, but not more in evidence than need be. Married quarters, with laundry and drying-ground, should be placed in retired positions, and as well screened from the single men's quarters as the site will allow. Canteens and recreation rooms should be conveniently located for both married and single men. The sergeant's mess should have a good frontage and convenient to the quarters, consistent with not being too near the men's barracks and regimental institutions. Officer's quarters and mess should have the best available frontage and if possible on a road not used as a thoroughfare by the men. The quartermaster's stores and his private quarters may be near the officer's mess and equally convenient to the regimental stores and shops. These latter should be arranged on roads for the easy access of carts, while coal-yards need to be located centrally to avoid unnecessary fatigue. The regimental offices and guard-room are best placed at the entrance to the group of barrack buildings which they serve. The parade should be of such a size as to measure at least 150 by 100 yards, with a drill-shed either adjoining it or conveniently near. The whole place should be arranged with a view to easy approach, simple drainage, symmetry, and free access of air and sunshine to all occupied buildings. The intervals between occupied buildings should not be less than twice the height from ground to eaves.

These then are the various items and their desired relation to each other

which have to be worked into any design of block plans for barracks. Their successful attainment is not always easy owing to exigencies of site, but before considering a typical site plan of what a barrack may or should be,

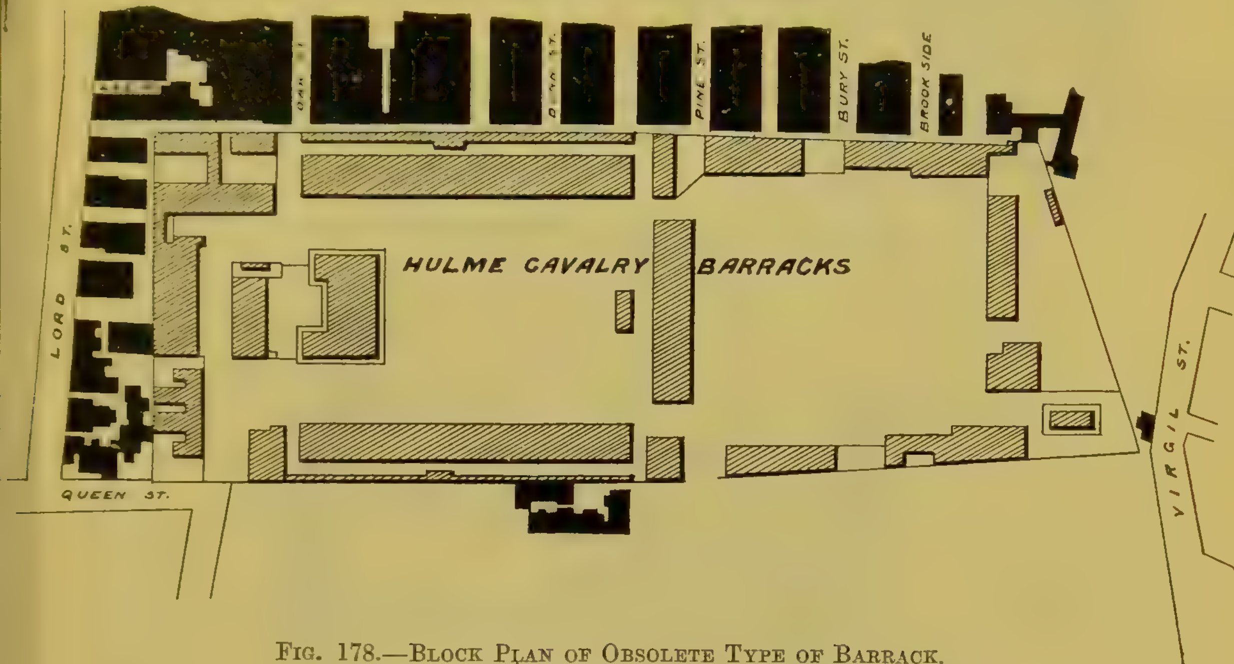


FIG. 178.—BLOCK PLAN OF OBSOLETE TYPE OF BARRACK.

attention may be directed to Figs. 177 and 178, which represent two instances of what a barrack block plan should not be. The former, an old block plan of Linen Hall Barracks, Dublin, is an instance of abnormal deficiency of internal freedom of air circulation, owing to the barracks being too con-

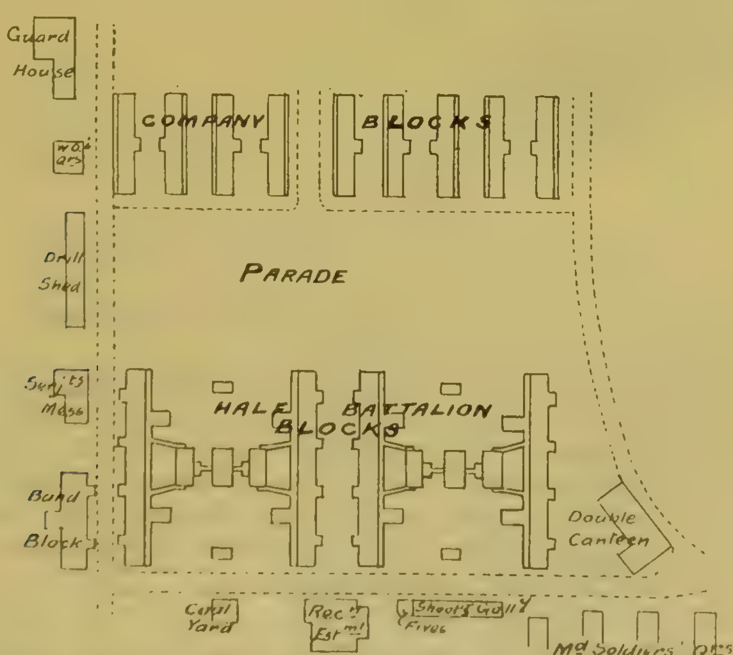


FIG. 179.—BLOCK PLAN OF OLD AND NEW TYPE OF BARRACK

centrated. Fig. 178, showing plan of Hulme Barracks in Manchester, is an excellent example of a most objectionable type of barrack caused by crowding them against the outer wall, and subjecting them not only to their own

nuisances but also to those of the crowded streets of a very dirty part of Manchester, which touch the barracks all round. Our own experience of these barracks indicates the real facts to be much worse than the drawing shows, owing to the height of some of the surrounding mills.

As representative of what a well thought-out block plan for barracks may or should be, Fig. 179 represents two new barracks at Colchester. These show two stages in design of barrack blocks, namely the single company block type in Sobraon barracks, and the half battalion combined or verandah type in the Gujerat barracks. There are certain defects in the plan which

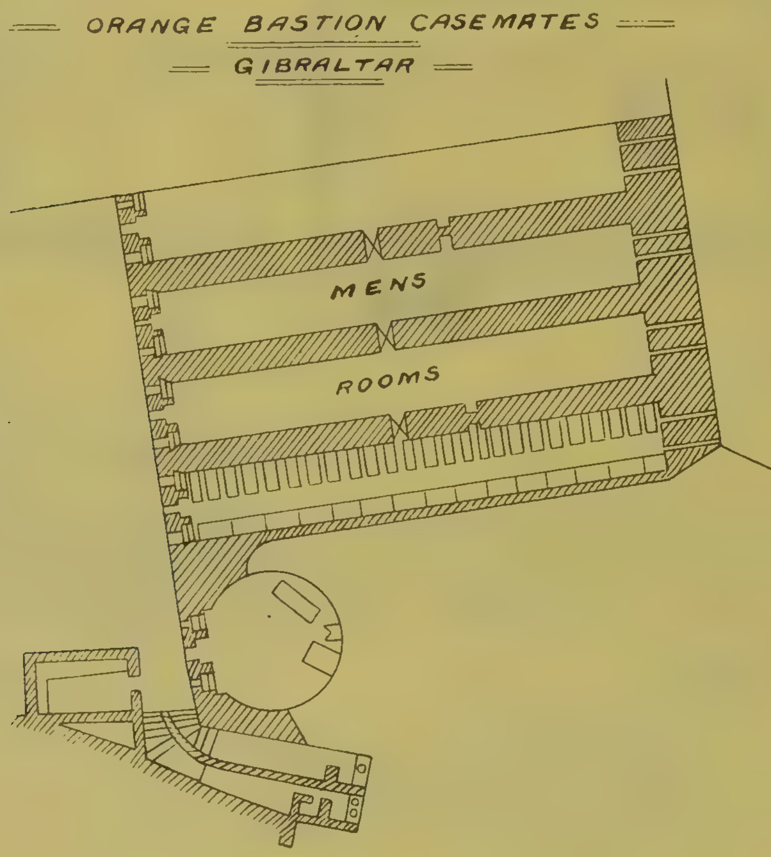


Fig. 180.—Block Plan of Casemate Barrack.

are due to limitations of available site; but it illustrates the essential difference between old and new ideas.

We may now consider the plan of actual barrack buildings. Of these there are many types, but, as a rule, barracks are best constructed of only two storeys. Frequently, the ground floor may be, with advantage, used for libraries, day rooms and administrative purposes, but this is not practicable as a rule. Basements should never be utilised as barrack rooms, they are always liable to damp and consequently to be unhealthy. Barrack rooms over stables are equally objectionable.

Fig. 180 shows a typical instance of an objectionable kind of barrack building common in citadels and fortresses. In this case, which represents the Orange Bastion casemates, Gibraltar, long lines of beds nearly touching each other are arranged on either side of a lengthy casemate, lighted and ventilated practically from one end only. Such an arrangement would be inadmissible in a modern building, but are difficult to amend in older defensive works. Figs. 181 and 182 show later developments of soldiers'

barrack rooms. These are arranged now usually in company blocks. Each block consists of two non-commissioned officers' rooms and four soldiers' rooms, each of which holds 24 men; the whole constituting a two-storeyed building with central staircase. The size of the rooms is such that each soldier gets not less than 600 cubic feet and 57 feet of superficial area. The beds should all have their heads against external walls, and there should be a passage not less than 18 inches wide on at least one side of each bed. Each company block has two ablution rooms, length 15 feet, breadth 7 feet 6 inches, and height not less than 9 feet. Basins are allowed at the rate of 14 per cent., each company block having 12 basins in the two ablution rooms. In each barrack room special outlets are provided, which should be at the rate of not less than one square inch clear cross-section area to 60 cubic feet of room space. Fresh air inlets should also be provided at the rate of one square inch to every 60 cubic feet of room space, except where ventilating grates are used, in which case one square inch to every 120 cubic feet only is required, the grates being constructed to supply half the necessary amount of fresh air, warmed to 60° F. Cold fresh air should be admitted in an upward direction at a height of 8 to 10 feet from the floor; warm air inlets of ventilating grates should not be more than 8 feet above the floor. In a barrack room two outlet shafts, each 14 inches by 9 inches, are provided, also 8 inlet shafts, five with an area of 10 square inches, and three with an area of 20 square inches. There are two ventilating grates in each barrack room, the air shafts being arranged to supply half the fresh air required. The external openings of the air ducts must be placed above the damp-proof course and not less than 18 inches from the ground.

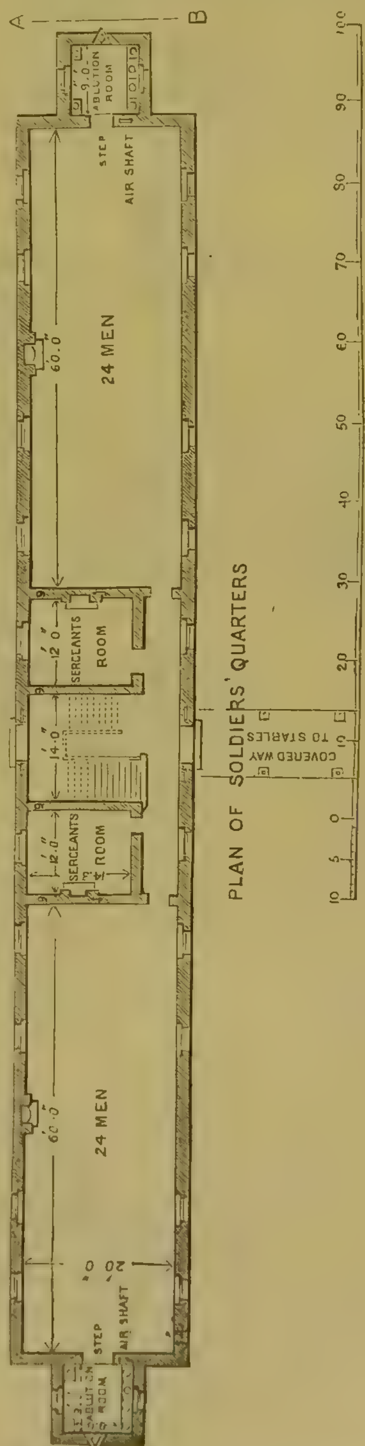


FIG. 181.—PLAN OF SINGLE COMPANY BARRACK BLOCK.

These designs have been recognised company types for some time; their chief defects are the existence of unequally spaced windows and the difficulty of avoiding three beds together. A room for twenty-four men is a convenient division for administrative purposes, as representing a section, but gives a room rather difficult to warm uniformly. Another defect in this type of barrack is the absence of dining halls for the men, the result being that the barrack room is at once sleeping room, living room and eating room, a combination of functions which, while bad enough for a single occupant, becomes intensely so when the unit space is common to some score or more of individuals. It is to obviate some of these objections that the new half-battalion combined barrack has been designed; this type may be taken to

represent the most modern arrangement of barracks in our service. The complete element is shown in Fig. 183, and consists of two double storeyed blocks, each holding two companies, facing inwards towards dining-halls, and cook-houses built between them, and communicating with them and

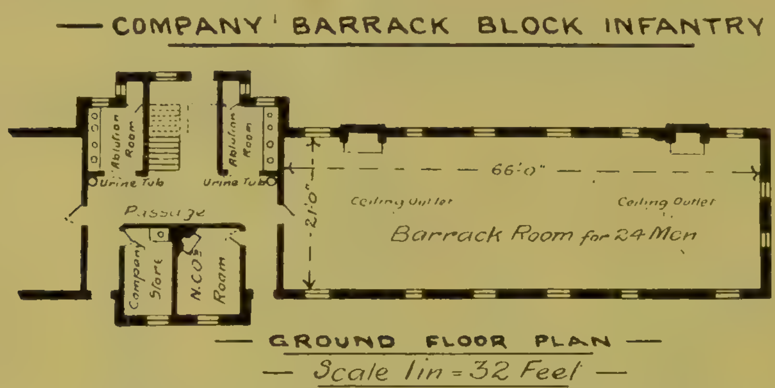


FIG. 182.—PLAN OF SINGLE COMPANY BARRACK BLOCK.

with each other by means of verandahs and covered ways. These blocks are arranged in 12-men rooms with passages between, leading from the verandahs on the inside to ablution rooms on the outside, there being a through communication *via* the latter on the ground floor. This, the most recent arrangement of ablution rooms, is a distinct sanitary improvement. So is

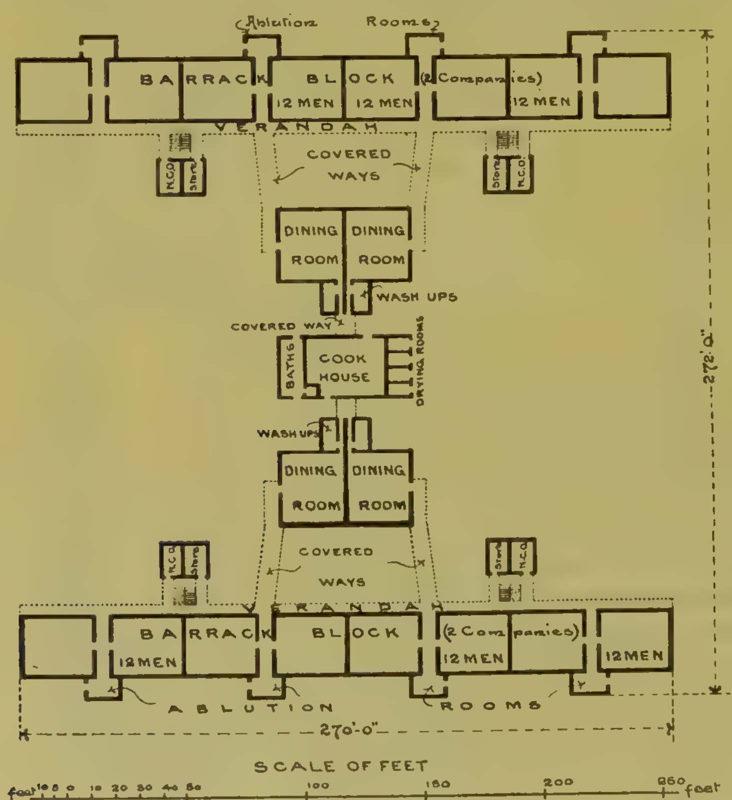


FIG. 183.—HALF-BATTALION BARRACK. (VERANDAH TYPE.)

the reducing of the barrack room itself to accommodate only twelve men: this smaller size renders the room much more homely and facilitates the squadding of the men on some principle of mutual compatibility, while at the same time lending itself either to extension or cubicle construction.

This last idea will not, we think, be satisfactory in the army; the majority of the rank and file are against it and, from trials of the system which have been made, it interferes with that free perflation of air through the rooms, so desirable to be maintained in all soldier's barrack rooms: it is, moreover, prejudicial to discipline. In a few words, the modern barrack room may be described as a room 36 feet long by 23 feet 6 inches wide, and 10 feet 6 inches high. It accommodates 12 men, and has three windows, two feet and a half by six feet on each side. A bed is placed in each corner and the others in pairs in the spaces between the windows. At the end of the room opposite the door is a fireplace of glazed fire-brick, with solid hearth; in connection with it is a warm air inlet and a foul air outlet. In addition, louvred ventilators are placed in the walls between each bed at a height of eight feet from the floor. At the other end of the room is a small ventilated cupboard for storing cleaning materials; no food is allowed to be kept in this cupboard or in any part of the barrack room. Rooms of this type are amply ventilated and afford sufficient space, being at the same time bright, homely and readily kept clean.

The dining-room block is shown divided into two company dining-halls, which communicate through company wash-up rooms direct to the serving windows of the cook-house on either side. This arrangement, while facilitating the rapid and hot service of meals, enables the crockery and food remains to be kept outside the dining-halls and barrack rooms. The cook-house is arranged for the double service, and at either end are provided bath rooms (four for men and one for N.C.O.s) and drying-rooms (one per company). The latter, as well as the dining-halls, are heated from a boiler room in a basement below, which supplies also the hot water for use in bath-rooms, cook-house and the wash-ups. The rooms for N.C.O.s with the company stores and staircases are located on the inner side of the barrack room block verandah, opposite the centre of each company. The windows to the barrack rooms are of special design to permit of the ready conversion of the rooms into dormitories with separate cubicles for each individual soldier. The estimated cost of these half-battalion barrack blocks is, notwithstanding the greater advantages and conveniences, very little more than that of similar accommodation provided separately on earlier plans.

The barrack accommodation for a cavalry regiment is based upon the organisation of the unit, viz., the squadron. Each regiment has a pair of barrack blocks arranged in the same manner as the infantry company blocks. Barrack rooms are not to be built over stables.

Stabling is provided for three service squadrons and one reserve squadron, 490 stalls for the whole regiment. There are six half-squadron blocks, each containing 72 stalls, but if desired the 72 stalls may be provided in two troop blocks of 36 stalls each. The reserve squadron has 34 stalls for remounts and 24 stalls for the remainder of the squadron.

All stalls should have a length of 11 feet and a width of 5 feet 6 inches and the height must be sufficient to give at least 1500 cubic feet per horse. The central passage between two rows of stalls should not be less than 9 feet wide, and the passage in rear of a single row of stalls should not be less than 7 feet wide. The windows must be arranged to give 9 feet of glass space for each horse; all stable windows must be made to open. The roof should be provided with continuous ridge ventilation. Fresh-air inlets should be provided along the eaves, giving 144 square inches per stall. When barrack rooms are built over stables, foul-air shafts must be carried up above the roof, and to increase the draught they should either be in connection with smoke flues or provided with exhaust cowls of approved pattern at the

top. These shafts should have a sectional area of at least 18 square inches per horse, and should extract from near the middle of the length of the stable when possible.

The preceding types of barrack are all designed for home or temperate climates; in tropical countries, the essential principles for similar buildings are the same, the main difference between the two being that the walls and roofs are thicker coupled with the provision of a wide verandah running all round the building. The general style of tropical barracks may be described as long, thin, somewhat narrow lines of buildings arranged *en echelon*, with thorough cross-ventilation and high plinths. The new barracks in India are for the most part of a single storey, but many of the older ones are two-storeyed. The number of men in a room never exceeds 24: each man getting in the plains of India 90 feet of floor space and 1800 cubic feet; in Indian hill stations the allowance is as at home. In foreign garrisons other than India, the floor space varies from 60 to 80 square feet, and the cubic space from 630 to 1000 feet. Few of the barracks abroad are provided with dining-halls, the men usually eating their meals either in the rooms or in the verandahs. In the tropics, the kitchens need to be protected from flies by means of wire gauze to all windows and doors. It would further be a step towards better sanitation, if in India and our other tropical garrisons the multiplication of small company cook-houses were abolished; and a single large cook-house and proper dining-hall provided in all barracks. Until this is done, the chances of food pollution are unnecessarily multiplied.

Although much has been done, in recent years, to improve the general standard of comfort for soldiers in barracks, it must be confessed that, even now, the average barrack room is far from being a cheerful and commodious home for a man of a sensitive nature. In this country, the two chief defects in ordinary barrack rooms are inadequate lighting and heating. The main obstacle to amendment lies in the financial question involved, but we think this to be exaggerated. To substitute better types of fire-grate in barrack rooms in lieu of the so-called ventilating Galton grate would not involve an enormous outlay of public money, neither would the provision of more numerous and better gas or electric lights in place of the present sparse and feeble sources of artificial illumination. The ventilation of barrack rooms, which once was much neglected, is fairly satisfactory at the present time. If anything, we think the tendency in the immediate past has been to rather over-ventilate; now, however, the part played by smoke flues as outlets and leaky doors and windows as inlets is better understood and the provision of needless ventilators avoided.

In tropical and sub-tropical climates, if barracks are not made too broad, and are properly placed, the same principles of ventilation may be applied to them as in barracks at home. The perflation of the wind should be obtained as freely as possible. The numerous doors and windows, however, render it unnecessary to provide special inlets; outlets should, as at home, be at the top of the room, either along the ridge, or, if of shafts, they should be carried up some distance; if they are made of masonry, and painted black, the sun's rays will cause a good up-current. The area of the shafts is ordered to be 1 square inch to every 15 or 20 cubic feet, with louvres above and inverted louvres below. In the lower rooms these shafts are built in the walls, while in the upper rooms they are placed in the centre of the ceiling. In many tropical countries, at certain seasons, the air is both hot and stagnant; in such stations artificial ventilation must be employed, and the forcing in of air offers greater advantages than the method by aspiration. The wheel of Desaguliers was introduced into India many years

ago by Rankine, and, under the name of "Thermantidote," is frequently used in private houses and military buildings. The great advantage of it is that the air is put not only in motion but can be cooled by being forced through wet grass mats suspended in a short discharge tube. The common fan or punkah acts too as a ventilator, as it displaces masses of air; but its value in this respect is probably small.

Of late years the use of *hut barracks*, both in peace and war, has increased in our army. In peace, their first cost is small, and they are healthy. In war time, they afford the means of housing an army expeditiously, and are better adapted for winter quarters than tents.

The ground occupied by a hut should be cleared, levelled, and drained. The hut should be provided with ridge ventilation and projecting eaves to carry off the rain-water from the foundations; it should have the requisite number of windows, and should be raised sufficiently above the ground to allow a free current of air to pass underneath the flooring. In hot climates the roof and sides should be double, if these latter are not protected from the sun by verandahs. Like permanent barracks, they are best placed *en échelon* to receive the full advantage of winds. Their ventilation is effected by openings in the ridge, or outlet shafts may be used, passing through the roof and terminating in louvres, with inlets under the eaves. Warming may be effected by the use of stoves or an open grate; the latter is preferable, as it assists in ventilation. At home stations, where hutments are in use, the floor space per man is 50 square feet and the cubic space 500 cubic feet; at stations abroad the floor area per man varies between 50 and 70 square feet, and the cubic space between 500 and 850 cubic feet.

The construction of huts depends on whether they are used for temporary purposes or whether they are intended to be of a more or less permanent character. In the latter case, the sides are built usually of brick. What are known as Döcker huts have been favourably reported on and much used both in our own and the German army. They are made of wooden or iron frames, covered with a kind of felt, lined with canvas. They are very portable, and the fastenings are so arranged that they can be put together in a very short time. These huts are well ventilated by windows, cross-louvres and ridge ventilators; if so desired they can be readily warmed.

In addition to these, there are a variety of other huts differing from each other only in the nature of the material of which they are constructed; in general design and type they are similar. As a rule, huts should not be made to accommodate more than 24 men.

In all barracks, an important detail is the provision of suitable *married quarters*. In the older type of barrack, the only quarters provided for married soldiers consisted of single rooms arranged four on a floor, two on either side of a central gangway and staircase, on two or three floors. The next development or concession to decency was the three-roomed quarter, consisting of a living-room, bedroom and scullery: a few of these are still to be found in existing barracks. Later followed what are known as the barrack attic and the depôt type of married quarter, in which differences were made in the number of rooms and the style of their finish for allotment according to the rank of the occupant. Up to this period, domestic conveniences were entirely detached from the quarters. The next stage of development was the verandah type in which these conveniences were arranged at the ends of the blocks, and at the same time the common sense system was introduced of allotting the different sized quarters according to the number of a soldier's family instead of according to his rank. On this basis, all quarters for married soldiers were reduced to three classes, namely

" a," " b " and " c," without distinction as to finish or rank of the occupier. The " a " quarter has one bedroom, the " b " quarter has two bedrooms and the " c " quarter has three bedrooms, in addition to, in all cases, a living-room and scullery. In the latest types, as represented by the self-contained attic and self-contained verandah quarters, a separate water-closet is given to every quarter. A still later type of quarter is a modern adaptation of the old depôt variety, in which the quarters consisting of living-room, scullery and two bedrooms with water closet are all alike and two-storeyed; each pair of quarters is so arranged that by throwing one bedroom of any quarter into the next we get a three and a five-roomed quarter, *i.e.*, an " a " and " c " quarter in place of two " b's ". These are comfortable working men's quarters without being luxurious, and the design constitutes a notable approximation of the military requirement to that of the corresponding social class in civil life.

In tropical garrisons, the married people's quarters are grouped usually in one storeyed blocks, each block holding the married people of a company or troop. Two to three rooms only are provided for each family, but as the quarters embrace verandahs, 12 and 10 feet wide, at front and back, supplementary accommodation is readily arranged, if required.

The two subsidiary services of water-supply and removal of excreta and refuse in connection with soldier's barracks have not been mentioned so far. They play just as important a part in military garrisons as they do in civil communities. *Water-supply* presents no special features in a barrack other than those common to it in an ordinary house, and the same principles as to source of supply, storage, purification and distribution hold good under this heading as under those considered in Chapter II. The amount of water supplied daily in the army is 20 gallons to every adult and 10 gallons for every child.

Latrine accommodation in barracks is provided for single non-commissioned officers and men at the rate of 5 per cent.; the same ratio holds good for urine stalls. When dry earth-closets are used, the provision of seats is at the rate of 7 per cent. In most barracks at home, water carriage of sewage is available: the type of closet is of a very simple nature and the flushing either done automatically or by hand every three hours. In some of the newer barracks, ordinary water-closets with individual flush tanks are provided. The usual location for closets and urinals for single men's barracks is in a detached block conveniently situated for ready access from the barrack rooms. For some types of barrack block the closets are placed in the centre of the building, near the head of the staircase. For night convenience, the almost universal arrangement in barracks is the placing of a wooden or metal urine-tub immediately outside each room; this tub is removed in the early morning. In the newer barracks, this objectionable feature is being obviated by the provision of fixed urinals of conventional pattern on the stairway landings; these urinals are only used at night, being kept locked during the day. The dry earth-closet exists in a few barracks at home and is found to work well, the usual arrangement being the provision of a pail or portable midden placed under apertures in a well fitted seat, with boxes of dry earth from which, by means of a scoop the user covers the excreta over. As many soldiers are familiar with this system before they enlist, no difficulty is experienced in getting them to use these places properly. The pail contents are removed daily. This work is done usually by a civil contractor, the ultimate disposal of the material not being within the purview or responsibilities of the military officials.

In India and most of our foreign garrisons water carriage of sewage is

practically unknown, the dry earth system being almost universal. For many years, this system has been considered to be admirably adapted for tropical needs, and from a purely administrative point of view so it is. But the considerable incidence of enteric fever in garrisons where this conservancy method is in force, coupled with a more accurate knowledge of the vitality and fate of the enteric bacillus in soil, has caused doubts to arise among experienced army medical officers whether the dry earth midden or pail, however successful at home and in a moist climate, is altogether an unmixed blessing in hot and dry climates. We confess to be ourselves among those who distrust the efficiency of a dry system of barrack latrine in arid and tropical countries. If we could ensure the method being carried out perfectly, many of the objections to it would disappear; but we cannot ensure perfection in details which are essential. The first difficulty arises with the soldier himself, he often fails to cover his excreta *completely* with earth; at home or in a temperate climate this matters little except in the hottest season, but in a tropical or sub-tropical country, where flies are present everywhere in enormous numbers, the slightest failure to secure absolute and complete covering of the excrement with earth means the inevitable dissemination of this objectionable matter by these insects back to man and his food. The next difficulty arises from careless handling, removal and disposal of the material by the scavengers deputed to perform this work. In nine cases out of ten, this means native labour, and in a tropical country complete supervision is often impossible. The pail contents are transferred to iron receptacles with close-fitting lids from which they are daily emptied into special tank carts for transfer to and burial in land allocated for the purpose. The possibilities of mishap in the course of these necessary manipulations are many, the result being that offensive material is spilled about or exposed to flies and other saprophytic creatures who bring it back to man's immediate vicinity. Again, the final disposal on or into land in a tropical country is full of fallacies. The only safe mode of disposal is deep burial; in practice this can be done rarely. The ordinary procedure is superficial burial in or on the soil; in arid districts this means rapid desiccation, pulverisation and prompt dispersal by the first wind that blows, and in times of dust storm this means translation for miles. Lastly, there is the difficulty of supplying to the latrine dry earth which is not itself excrement tainted. Too often such earth is soil brought back from land whereon excrement was disposed recently; to sterilise it before issue is impracticable, therefore the average dry earth latrine in a tropical country becomes in too many cases nothing but a centre of infection, the air of which is laden with excrement-tainted dust and infested with flies, the bearers of equally disease-giving matter.

To those familiar with the conditions prevailing in many of our Indian garrisons, this is no overdrawn picture. The difficulty is how to find a remedy. Some advocate a more thorough supervision and closer attention to detail; this has been tried and found wanting. Others suggest and have tried burning, but a very short experience of attempting to burn large volumes of excreta and earth will demonstrate the futility of that method for general use. Any system of water carriage on the lines of our home practice is equally impracticable, as there is not the necessary water. There appear to be three possible substitutes for the existing dry earth system, consistent with the ordinary conditions of our tropical garrisons and barracks. One is to change the whole rationale of the latrines and convert them from dry to moist. This could be done by locating above each pail or midden a small tank containing water with or without some antiseptic deodorant. Each user would be called upon to release or discharge from this tank a certain

quantity of the liquid so as to cover the excrement. The pail contents would be removed in the usual way by hand and disposed on land. We are not aware of this method having been tried; it would get rid of the dry earth with its attendant dust-laden air in the latrines, and would serve to cover up the excrement from the attacks of flies. The objections to its application centre mainly in the expense of providing the necessary tank fittings and the water, medicated or otherwise. That it would be an improvement on the present dry installation is certain, and as a possible arrangement in some places is worth bearing in mind.

The second proposal involves the retention of earth in the latrines, but to use it in a moist state; the moistening being done by means of water or crude mineral oil. The latter is preferable as it limits inducements for mosquito breeding, and, too, would be inimical to flies settling on or about the excretal material. The subsequent handling and disposal of the night-soil would be the same as in an ordinary dry-earth latrine. We believe this method has been tried in India and found to work well, the main difficulty is the expense of providing the mineral oil; but if only the lowest grade oil be used the cost should not be prohibitive. The admixture of an inflammable oil with the earth and excrement would facilitate any attempt at incineration, if tried. We would like to see this form of moist-earth latrine given a full trial.

The third alternative is to discard the addition of any deodorant or covering material to the excreta deposited in the pails, but to have the contents of each pail transferred as soon as possible to a closed metal tank in which, once a day, the contents are subjected to a temperature of 180° F. for a few minutes by means of a fire located under it. This secures practical destruction of such germs as those of enteric fever, dysentery, or cholera, if present; after which this presumably non-pathogenic fæcal material is carried away in covered carts to be placed on land. This method is said to have given good results in certain Indian garrisons where it has been tried. We hope that experiments on one or other of these lines will be persisted in, and that the prevalent dry-earth latrine will soon become a sanitary curiosity in our tropical garrisons just as the old pan-closet has become in this country.

Whatever form the latrine may take, it is desirable that a double set of pails be provided, so that the same pan is not in use on two consecutive days. On the off day, the pan, after being well cleaned out with kerosene oil and some crude phenol, should be left exposed to the air. All the seats should be washed daily with soft soap and water, and then both surfaces brushed over with kerosene oil. Finally, any loose soil on the floor should be watered twice a week with kerosene oil, well rammed down and on no account be brushed or swept. All scraps must be removed by hand. So far as possible, the latrine should be regarded as a company or squadron institution, and men be taught to use only their own company or squadron latrine. These measures will be found to prevent flies haunting the latrines and serve to localise any chance of infection.

As regards the final disposal of the excrement there are two essentials; these are:—(1) let the removal be done always in daylight and when adequate supervision can be imposed; (2) never dispose of this material by superficial burial, let the excrement be buried at least one foot deep, not more, and see that it is covered with fine earth, not earth in lumps or clods; if this be done, we reduce the chances of these areas becoming so many breeding-places for infected flies.

Military Hospitals.—In the construction of hospitals, the great points to be secured are:—(1) purity of internal atmosphere; (2) abundance of

pure air and sunlight within the building; (3) facility of administration and discipline. The realisation of these principles involves the selection of a healthy site for the building, simplicity of plan and construction, a sufficient number of wards properly placed, a certain arrangement of wards, proper ward proportions, a suitable number of offices, stores, &c., and easy means of communication throughout the building. The first of these conditions is met by placing the sick in detached buildings, with such an aspect as will afford the freest air and the greatest light; this is best effected in hospitals built on the pavilion plan, in which the sick can be treated in small detached and perfectly ventilated buildings, and where there is no possibility of the air of one ward passing into another.

The ward unit is the foundation of the hospital plan, and the ward construction and proportions must be based on the number of cubic feet to be allowed per bed. In wards each man should have at least 85 square feet of superficial space and 1200 feet of cubic space. This is the amount allowed by regulations at home, but, if possible, a larger space should be given. In tropical climates (exclusive of India), 1500 feet of cubic space is allowed to

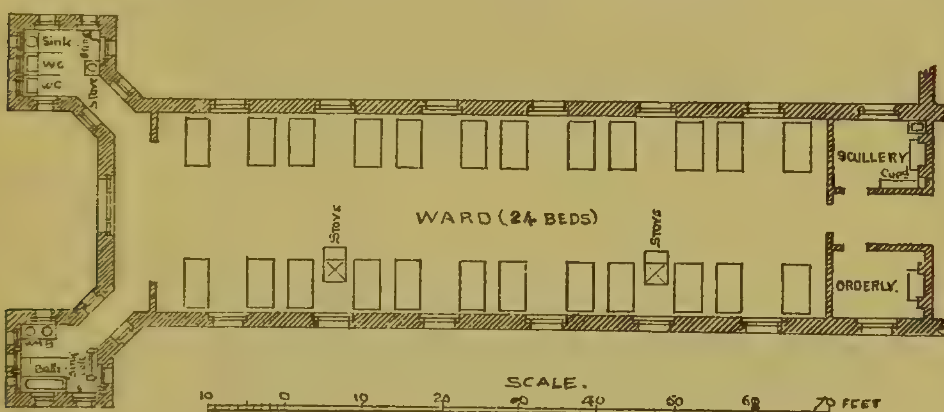


FIG. 184.—PLAN OF MILITARY HOSPITAL WARD.

each man, or an amount as may be specially authorised for each command. In India, the sick soldier gets 120 square feet of floor area in hospitals, and from 1630 cubic feet of space (in the hills) to 2400 cubic feet (in the plains).

The total number of beds required in military hospitals, during peace time, is taken usually as $3\frac{1}{2}$ per cent. on the normal strength of the garrison, exclusive of officers. The ward blocks are rarely more than two storeys in height. The actual number of beds in the large wards is fixed by considerations of economy in nursing and administration generally. The limits may be taken at 20 beds and 32 beds respectively. An ordinary ward of 22 beds has the following dimensions, viz.:—length, 80 feet; breadth, 24 feet; height, 14 feet. For each bed the minimum floor space is 85 square feet, and cubic space 1200 feet. Every bed should be next a window, therefore the beds should be arranged as far as possible in pairs, with single beds only in the corners. The wall space between windows for each pair of beds must not be less than 9 feet, and that for a corner bed not less than 4 feet 6 inches. The space for windows between each pair of beds should not be less than 4 feet 6 inches. The above conditions give a minimum total wall space of 6 feet 9 inches per bed, while the breadth and floor space prescribed allow 7 feet 1 inch.

The ventilation of the wards in our military hospitals is on the same plan as for barracks, that is, by windows, ventilating grates, and special inlet and outlet shafts; the dimensions of these latter are, however, doubled.

The wards are warmed by one or more ventilating grates of approved pattern, while windows are placed opposite each other on both sides of the ward.

The lavatory, bath-room, and water-closets with slop-sink are placed always in special disconnected annexes. In the case of very large wards, two annexes are provided as shown in Fig. 184; one containing the lavatory and bathroom and the other the water-closets and slop-sink. For the small wards, a combination annexe, containing water-closets, bath, lavatory, and slop-sink is used; but it is desirable to separate the portion containing the water-closets and slop-sink from the remainder by a brick wall from floor to ceiling. Water-closets are provided at the rate of 14 per cent., but no ward containing 8 beds or over has less than 2 water-closets. Three water-closets are, however, sufficient for a 28-bed light case ward. Ward blocks are usually connected with each other and with the administrative block by covered corridors. These are rather of the character of light covered bridges than of enclosed buildings. In large garrisons special Isolation Hospitals are provided. The ward blocks for infectious cases should not be more than one storey in height; they should be well separated from each other, and closed corridors should never be provided. The floor and cubic space should not be less than 110 square feet and 1500 cubic feet, respectively, per bed. In small garrisons, beds for infectious cases should be arranged in at least three independent pavilions of the station hospital so as to admit of the separation of three different infections.

Tents.—A good tent should be light, so that it may be easily transported, readily and firmly pitched, and easily taken down. It should completely protect from weather, be well ventilated, and durable. It is perfectly easy to devise a tent with some of these characteristics, but not to combine them all. The tents used in our army are as follows:—

The Bell or Circular Tent.—These tents exist as two patterns, single-fly and double-fly. They are intended to accommodate 15 healthy soldiers or 4 sick men. They are made of duck, are provided with 6-inch eaves to carry off water clear of the walls, and have three ventilators covered with bibs. In both patterns the floor diameter is 15 feet, the height of the walls is 2 feet 2 inches, and the height of the pole 9 feet 9 inches. The weight of the single-fly tent is 83 lb., that of the double-fly 112 lb. The men lie with their feet to the pole and their heads towards the canvas; with 18 occupants the men's shoulders touch.

The Marquee Tent.—This tent is two-poled, with double flies. It consists of a lower quadrangular part, and an upper portion sloping from the top of the side walls to the ridge-pole. It is 29 feet long and 14 feet wide; sides are 5 feet high, and the height in centre from ground to the ridge is 15 feet. It gives about 375 square feet of floor area and some 3200 cubic feet. It is intended really for sick men and can accommodate 8 of these or 16 healthy men. It is provided with two ventilators, and a large flap at the top can also be opened for ventilation, and the fly can be raised. The weight of this hospital marquee (including the valise) is about 512 lb. A waterproof sheet is supplied, to put on the ground, and this weighs 145 lb.

It is a good tent when care is taken with ventilation; but there should be a way of raising one whole side, so as to expose every part of the tent, and if the height of the upright part were 6 feet, it would be more convenient. These tents are used for hospitals on the lines of communication and at the base, but form no part of the movable field equipment; they are used when buildings or bell tents are not available.

Operating Tent.—This tent is rectangular in shape and has a doorway at each end. It is fitted with six ventilators of the ordinary type, and also

with a large ventilator on each side to give extra light and air. The wall is permanently attached to the tent. The poles used with it consist of two upright poles and one ridge-pole, each made in two pieces. The dimensions of the tent are as follows:—length, 20 feet; width, 14 feet; height, 9 feet 4 inches; height of wall, 3 feet. The tent alone weighs 116 lb., and with poles and appurtenances complete, about 181 lb.

Shelter Tent.—There is no official shelter tent for the English Army on field service, but one is occasionally issued. It weighs 23 lb. and accommodates four men easily. The main difficulty with this class of tent is the lightness and liability to break of the supporting sticks; a further objection is their stuffiness and inadequate protection in wet weather.

In the German Army bivouac tents are in use. The component parts of the tent-poles and canvas are distributed among as many men (two at least) as are meant to be sheltered by it. The canvas part, which has the appearance of tanned waterproof flax, is rolled round the soldier's overcoat, which is strapped down on the top and sides of the knapsack, and in bad

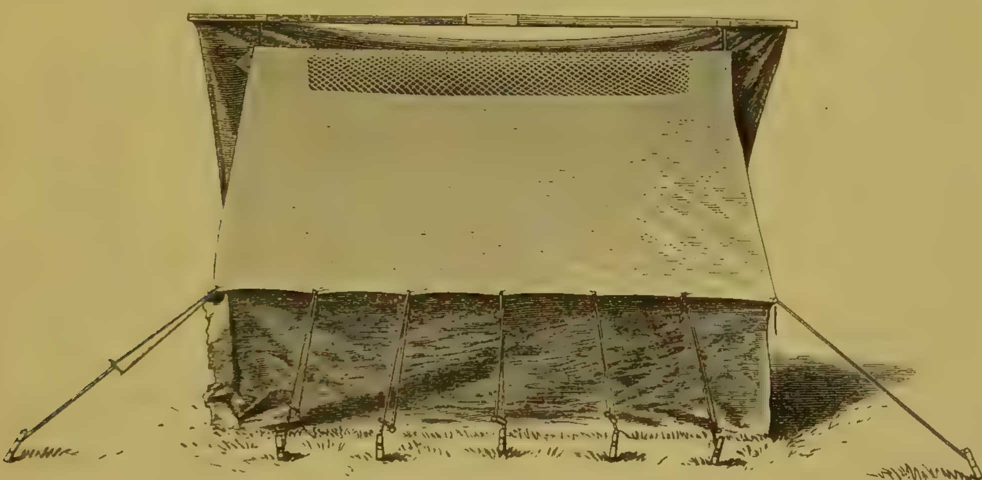


Fig. 185.—American Double-fly Net.

weather this tent section may be unrolled and worn as a waterproof *poncho* by the bearer.

The tents in use by the Indian Army are as follows:—

British Privates.—With two poles and ridge, double-fly. Length, 20 feet; breadth, 16 feet; height of walls, 5 feet 6 inches; height to ridge-poles, 10 feet 6 inches. Cubic space, 2373 cubic feet. This tent is used for inland service, and accommodates 16 healthy men or 8 sick. Weight, 900 lb.

Mountain Service.—With two poles and ridge. Length, 12 feet; breadth, 8 feet; height of walls, 10 inches; height to ridge-poles, 8 feet. Cubic space, 544 cubic feet. This tent is used for field hospitals to accommodate 4 sick. Weight, 140 lb.

General Service.—With three poles and ridge. Weight, 160 lb.; length, 14 feet; breadth, 14 feet; height of walls, 1 foot; height to ridge-pole, 7 feet. Cubic space, 686 cubic feet. This tent is used for field service, and accommodates 16 British or 20 native soldiers, or 25 followers.

General Service (small).—With two poles and ridge. Weight, 80 lb.; length, 8 feet; breadth, 14 feet; height of walls, 1 foot; height to ridge-pole, 7 feet. Cubic space, 392 cubic feet. This tent is used for field service, and accommodates 8 British or 10 native soldiers, or 12 followers.

The tents of foreign armies present no notable features, resembling for the most part our bell tents. Fig. 185 represents a tent suggested by

Munson for use in the United States Army; in appearance it resembles closely the so-called 80-lb. tent used by officers in India. The outer fly is enlarged and raised upon a light false ridge placed 1 foot above the true ridge. The canvas comprising the top of the tent under the outer fly is "cut out for a space 2 feet wide on each side of the ridge, and running the entire length of the tent except 1 foot front and rear. The canvas thus removed is replaced by heavy rope netting, having a mesh about 2 inches square." The tent fly is white in colour, while the tent itself is drab. Six patients are usually allotted to this tent, but more may be safely placed in it owing to the free ventilation. It was found in Cuba that Munson's tent was from 7° to 10° cooler than the regulation hospital tent, and from 10° to 18° cooler than the conical wall tent. In cold weather the tent was made as "snug as the old tent by merely placing an ordinary fly over the true ridge and under the large fly, and pegging it down so that the smaller fly rested against the tent roof and thus closed the large ventilating opening."

THE FOOD OF THE SOLDIER.

Frederick the Great is reported to have remarked:—"On sait que, qui veut bâtir l'edifice d'une armée, doit prendre le ventre pour fondement," and history is not without evidence that the great King of Prussia was correct in his views. The principles governing the selection of food and the formulation of a sound dietary have been explained in Chapter V.; these principles apply equally to the soldier as to the ordinary individual, but, apart from possessing adequate nutritive value and variety, the feeding of the soldier presents certain requirements peculiar to the conditions under which he serves; these are easiness of preparation, portability, and comparative inexpensiveness. For these reasons, we find that, taking the armies of one nation with another, the scale of rationing is often extremely defective. For many years it was notoriously so in our own army, but, as the result of notable administrative reforms, it can be now said that the British soldier is the best-fed fighting man in the world.

The British Soldier obtains his food-supplies from the following sources in *peace* time:—(1) From the Government a free issue of 12 ounces of meat and 1 lb. of bread daily at home garrisons, and of 1 lb. of meat and 1 lb. of bread when serving in India or other places abroad. (2) If efficient and nineteen years of age, he is allowed 3*d. per diem* towards the purchase of supplementary articles, such as extra bread, butter, potatoes, cheese, milk, vegetables, tea, sugar, &c. This money allowance the soldier does not handle as cash, in fact he never sees it. This daily allowance is a credit issue which is "pooled" or thrown into a common messing fund and administered by company and squadron officers for supplying daily to the men such articles as they themselves may desire. The men are grouped into messes, and each day, through their non-commissioned officers, draw in kind, according to their tastes, against the common fund. This system, introduced in 1900, has been an unqualified success, giving to the soldier not only a sufficiency of food daily, but a variety in accordance with his actual fancies. Of course it entails some administrative care and trouble, but with the non-commissioned officers and men co-operating heartily the labour involved is negligible. (3) In addition to the above, the soldier makes individual purchases either at the grocery bar or regimental shop, or from purely civil sources.

The nutritive value of the Government issue in kind it is easy to calculate;

on the home scale it is 1515 Calories, and on the Indian or foreign scale it is 1636 Calories. To make an estimate of the dietetic value of the food which the soldier obtains from the other two sources there are obvious difficulties. But, as illustrative of what the soldier actually does consume daily, the following three dietaries are instructive. Two were issued and consumed by men belonging to different corps in Aldershot, the third represents an actual day's consumption by a soldier in India. These three dietaries may be taken as typically representative of the food of the British soldier. It will be understood that included in the details are the Government issues of meat and bread; these are incorporated and worked up into the various dishes which are rendered available by the supplementary issues obtained through the messing fund.

Diet A (Aldershot).—Breakfast:—fried liver, 6 ounces; bread, 6 ounces; tea; sugar. Dinner:—beef, 5½ ounces; pease soup, 7 ounces; potatoes, 16 ounces; bread, 5 ounces. Tea:—bread, 4 ounces; dripping, 1 ounce; tea and sugar. Supper:—porridge, 2 ounces; sugar. The nutritive value of this man's food for the day was estimated to be 2909 Calories.

Diet B (Aldershot).—Breakfast:—fried bacon, 3 ounces; bread, 7 ounces; tea; sugar. Dinner: meat, 5 ounces as Irish stew, including haricot beans and lentils 1½ ounce; potatoes, 10 ounces; bread, 5 ounces. Tea:—bread, 4 ounces; jam, tea and sugar. Supper:—fish and potato pie, 8 ounces. This man's diet was estimated to be equal to 3116 Calories.

Diet C (India).—Breakfast:—bacon, 3 ounces; two eggs; bread, 4 ounces; tea and sugar. Dinner:—beef, 5½ ounces; Yorkshire pudding, 4 ounces; potatoes, 8 ounces; bread, 4 ounces. Tea:—currant cake, 5 ounces; tea and sugar. Supper:—curried fish, 4 ounces; bread, 3 ounces. This man's diet was calculated to be equivalent to 3090 Calories.

In all the above dietaries, the weights refer to cooked food and as actually eaten. No allowance has been made for the nutriment contained in beer or other drink taken by the men. It will be seen that, taking these three men's diets as typical of the kind and variety of food which the soldier gets in a well-administered corps during peace times, the average soldier is remarkably well fed. It will be readily understood that there are remarkable variations; some men are by nature small eaters, just as others are the reverse. The general quality of the food supplied in our army is high; the issue of tinned meat is now practically discontinued in peace, at most it constitutes an issue once a week. The main criticisms which can be made on the feeding of the British soldier have reference less to the quality of the actual food than to the manner in which the men are often compelled to eat it. In barracks of recent design, where dining-halls are provided, these comments do not apply; but in places where the food has to be eaten in the barrack rooms, there can be no doubt the sanitary conditions are verging on the undesirable. In India and some foreign garrisons where food is cheap and the soldier has fewer opportunities for spending money than at home, the danger lies in the men getting too much rather than too little food. In the hotter seasons, the paucity of fresh vegetables is often a factor conducive to indifferent well-being; but the greatest danger to the soldier in India by means of his food is the ubiquitous presence of cook-boys and other low-caste natives in and about the lines. It would be far more conducive to clean food if the men cooked it themselves, and if the cook-houses in these barracks were planned and equipped in accordance with European practice and also fewer in number. The difficulty in all tropical or warm climates is the excessive presence of the common fly, which settles indiscriminately on food or fæces. For this reason, the greatest care needs to be taken to protect food and cook-houses from their presence; this can only be done by elaborate precautions to close all doors and windows with fine wire gauze.

In time of war or for active service in the field, a special ration is fixed by the Secretary of State, according to the climate and the circumstances of

the expedition. The following scale is adopted as far as possible :—1 lb. fresh, salt, or preserved meat; $1\frac{1}{4}$ lb. bread, or 1 lb. biscuit, or 1 lb. flour; $\frac{1}{6}$ ounce tea; $\frac{1}{3}$ ounce coffee; 2 ounces sugar; $\frac{1}{2}$ ounce salt; $\frac{1}{36}$ ounce pepper; $\frac{1}{2}$ lb. fresh vegetables when procurable, or 1 ounce compressed vegetables; also $\frac{1}{2}$ ounce lime-juice with $\frac{1}{4}$ ounce sugar, and $2\frac{1}{2}$ ounces rum, when ordered by the general commanding, on recommendation of the principal medical officer.

In the expedition to Khartoum, 1898, the European ration was as follows :—Fresh meat, $1\frac{1}{4}$ lb., or preserved meat, 1 lb.; bread, $1\frac{1}{2}$ lb., or biscuit, 1 lb.; tea, $\frac{1}{2}$ ounce; coffee, $\frac{1}{2}$ ounce, or cocoa paste, 1 ounce; sugar, 3 ounces; salt, $\frac{1}{2}$ ounce; pepper, $\frac{1}{36}$ ounce; dried onions, 1 ounce, or compressed vegetables, 1 ounce, or fresh vegetables, 1 lb., or beans, 3 ounces; preserved potatoes, 1 ounce; rice, 2 ounces; lentils, 1 ounce. The ration for natives was :—Bread, biscuit, or flour, 1 lb.; meat, fresh or preserved, $\frac{1}{2}$ lb.; coffee, $\frac{1}{3}$ ounce; sugar, 2 ounces; salt, $\frac{1}{2}$ ounce. The ration issued to men in South Africa, 1899–1902, was in accordance with the same scale, supplemented when occasion offered by such issues as jam, cheese, and pickles; but all experience shows that no reliance can be placed upon any special scale of ration laid down; so many contingencies may arise to prevent adherence to it, that it really constitutes but a standard with which the supply service will do its best to comply. If anything, our standard for a field service ration errs on the side of excess of protein in an unassimilable form; the issue of so much meat in the preserved and concentrated form is a mistake, 8 ounces of uncooked preserved meat is ample. The notable prevalence of the two extreme conditions of constipation and diarrhœa among soldiers on field service and rationed on the foregoing scale is explicable to a large extent by the indigestible nature of the meat element. It is a familiar fact to many that the great craving among men who have been a month or six weeks on such a field ration is for carbo-hydrate and fat, in the form of jam, sugar, bread and butter. A critical consideration of our field service food indicates its concentrated nature, and the curious lack of mass or ballast to stimulate the intestine to normal action. In practice, the meat is canned and the bread is represented by biscuit; theoretically they may and do represent so much protein, fat, and carbo-hydrate, but potentially their calorific value is small, because the assimilation of the proximate elements is so difficult.

For rapid movements, when transport has to be reduced to a minimum, the use of concentrated and cooked foods is all-important. In these circumstances pea and flour sausages, erbswurst, meat biscuits and other forms of so-called emergency rations are the best to use. Various types of these preparations have been discussed in Chapter V., but in this connection we would urge that a greater consideration might be given to the fact that both cheese and bacon are articles of food of high nutritive value, and as both are every-day food-stuffs with the class from which the greater number of our soldiers are drawn, it is not beyond the ingenuity of provision preservers to supply both in a form convenient for service needs. Our present emergency ration consists of a small tin cylinder divided into two compartments and weighing 10 ounces. One compartment contains 4 ounces of pemmican and the other 4 ounces of chocolate paste.

The issue of a spirit ration on service has been the subject of much discussion; the whole experience of recent wars is against its issue. There is perhaps no point on which there is a more unanimous opinion than that there should be no daily issue of a spirit ration. But although the daily issue of rum as a ration should be avoided, there are cases in which a ration

of alcohol has been found to be productive of the greatest service, even where alcohol in the form of rum and beer may be productive of much evil. The advantage which light red wines possess cannot be passed over. These, well diluted, are most refreshing drinks in hot climates; they should of course be used in moderation, and for young and "unseasoned" soldiers, probably total abstinence would be better. After a fatiguing march, red wine may be given with advantage; it has a recuperating effect, and may possibly be a preservative against disease. Alcohol should never be allowed before or during a march, but at the end, and then only in the form already indicated. It was formerly supposed to be a preservative against malaria; that this is not so is now abundantly proved by the experiences gained in India and South Africa. There is no evidence to show that the issue of a daily ration of rum has been productive of any good, and in many cases it has certainly done much harm. On the other hand, light red wine may be given with advantage, as it contains a large amount of acid salts and tannin, which probably assist in destroying pathogenic bacteria.

The following details concerning the feeding of men in some other armies may be of interest; it will be noticeable, compared with the rations of the British soldier, how short they fall of theoretical requirements.

Rations of the Indian Sepoy.—This dietary cannot be laid down with any exactitude, as the native soldier is drawn from various races, having varying caste prejudices. The rations issued in the Tirah Expedition, 1897–98, may be taken as a type of the native soldier's war ration:—Atta or rice, 2 lb.; ghi, 2 ounces; dhal, 4 ounces; salt, $\frac{3}{4}$ ounce; also meat and condiments on payment. In some later expeditions, onions and amchur have been issued.

The following ration has been suggested for Aden camel-drivers:—Biscuit or rice, $1\frac{1}{2}$ lb.; dates, wet, 1 lb.; ghi, 2 ounces; sugar, 2 ounces; coffee, $\frac{1}{3}$ ounce; salt, $\frac{1}{2}$ ounce; onions, when procurable, 2 ounces, or dhal, 4 ounces.

Rations of the French Soldier.—Under the present Regulations, in time of peace the Government furnishes the meat for the soldier's rations at about 35 per cent. under market price. This has proved a great advantage for the soldier. The State also furnishes bread (*pain de munition*) and fuel; the white bread (*pain de soupe*), as well as other articles, are bought from the funds of the *ordinaire*, or common fund of the company, battery, or squadron.

If biscuit is issued, 550 grammes (or 19·4 ounces) are given in place of bread. If salt beef is used, 250 grammes (8·8 ounces) are issued, or 200 (7 ounces) of salt pork. Haricot beans form the chief part of the dried vegetables.

In Algiers the ration of bread is also 750 grammes, or 26·5 ounces, and 8·8 ounces for soup, or biscuit 643 grammes. The meat is the same; 60 grammes of rice and 15 grammes of salt are issued, and, on the march, sugar, coffee, and $\frac{1}{4}$ litre of wine.

In time of war, the normal service ration is as follows:—Bread, 750 grammes, or biscuit, 600 grammes; rice, 60 grammes, or dried vegetables, 60 grammes; salt, 20 grammes; sugar, 24 grammes; coffee, 16 grammes; fresh meat, 400 grammes; fat or hog's lard, 30 grammes; condensed soup, 80·25 grammes. When fighting is actually taking place and great exertion is demanded from the soldier, the ration is increased as follows:—Rice, 100 grammes; sugar, 31 grammes; coffee, 24 grammes; fresh meat, 500 grammes; preserved meat, 250 grammes.

Rations of the United States Soldier.—The daily ration in the United States Army is as follows :—

Fresh beef, 20 ounces, or salt beef	22·00 ounces.
Or pork or bacon	12·00 ,,
Bread or flour	18·00 ,,
Potatoes	16·00 ,,
Peas or beans	2·40 ,,
Rice	1·60 ,,
Sugar	2·40 ,,
Coffee (raw)	1·60 ,,
Salt	0·25 ,,

Rations of the German Soldier.—The rations in time of peace are divided into the smaller and the larger victualling rations; the former for ordinary use in garrison, the latter for use in camps and in field manœuvres.

	Smaller Ration, in ounces avoir.	Larger Ration, as supplied for Camps, Marches, &c., in ounces avoir.
Bread	26·47	35·30
Meat (raw)	5·30	17·65
Or bacon	4·41	6·00
Or smoked meat (only in war time)	—	8·82
Rice	3·18	6·00
Or groats or grit	4·24	6·00
Or peas or beans	8·12	12·00
Or potatoes	53·00	71·00
Salt	—	0·88
Roasted coffee (exceptionally only in war time)	—	1·41
Brandy	—	3·53
Or beer	—	35·30
Or wine	—	17·65
Butter	—	1·76
Tobacco	—	1·41

The daily war ration is now as follows :—

Bread	26·50 ounces.
Fresh, or raw salt meat	13·25 ,,
Or smoked beef, mutton, ham, bacon, or sausage	8·82 ,,
Rice or ground barley	4·41 ,,
Or peas, beans, or flour	8·83 ,,
Or potatoes	53·00 ,,
Salt	0·90 ,,
Coffee roasted	0·90 ,,
Or raw coffee	1·00 ,,

Dismounted troops, field and horse artillery and train carry iron rations for three days, cavalry for one day, the dismounted troops carrying it on their persons, the cavalry on the saddle and the artillery and train on their carriages. An iron ration consists of 9 ounces biscuit, 7 ounces preserved meat (or 6 ounces bacon), $3\frac{1}{2}$ ounces preserved vegetables, $\frac{7}{8}$ ounce of coffee, and $\frac{7}{8}$ ounce of salt; the total weight of the ration, with packing, is 1 lb. 10 ounces.

Rations of the Austro-Hungarian Soldier.—The peace ration consists of the following :—

Bread	30·88 ounces.
Or biscuit	17·65 ,,
Meat	6·71 ,,
Suet	·62 ,,
Wheat flour	6·57 ,,
Or legumes	2·47 ,,
Or groats	4·94 ,,
Or millet	5·29 ,,
Or pearl barley	4·02 ,,
Or potatoes	19·77 ,,
Or rice	3·71 ,,
Sauer-kraut	5·54 ,,

The war ration consists of :—

Biscuit	3·53 ounces.
Flour	25·20 ,,
Beef	9·88 ,,
Or salt meat	6·00 ,,
Or bacon	6·00 ,,
Peas	5·29 ,,
Or groats	4·94 ,,
Or potatoes	8·82 ,,
Or Sauer-kraut	5·54 ,,
Suet	1·06 ,,

Rations of the Russian Soldier.—The daily scale of rations for a soldier in time of war is :—

Biscuit	1 lb. 13 ounces (or flour or bread, as in peace).
Fresh meat	$7\frac{1}{4}$ ounces, or $3\frac{5}{8}$ ounces ham.
Groats	$4\frac{4}{5}$,,
Salt	$\frac{4}{5}$,,
Tea	$\frac{9}{40}$,,
Sugar	$\frac{9}{20}$,,
Spirits	0·27 pint.

Rations of the Italian Soldier.—The peace ration of the Italian soldier is as follows :—

	Ounces avoir.
Bread	32·40
Meat	7·06 to 10·59
Bacon	0·53
Rice	5·30
Salt	0·53
Sugar	0·71
Roasted coffee	0·53
Wine	8·82

Rations of the Japanese Soldier.—The daily ration in peace consists of 6 go of rice ($5\frac{1}{2}$ go = 1 litre) or about 36 ounces in bulk, and 6 cents (or sen) for the purchase of beef, chicken, pork, or fish, and vegetables, tea, pepper, mustard, and miso, a kind of pea flour.

The daily field ration consists of :—

A—Daily issue.

Rice (uncooked)	1 quart or about 2 lbs.
Tinned meat or fish	$\frac{1}{3}$ lb.
Dried vegetables	$\frac{1}{4}$ lb.
Pickles	2 oz.
Sauce (*soyo*)	1 oz.
Bean-meal sauce (*miso*)	1 oz.
Salt	$\frac{1}{2}$ oz.
Sugar	$\frac{1}{2}$ oz.
Tea	$\frac{1}{7}$ oz.

B—Periodic issue.

Saké (a kind of spirit)	$\frac{1}{6}$ litre or $\frac{1}{3}$ pint.
Fresh meat	1 lb. with bone.
Cigarettes	20.

C—Irregular issue.

Japanese cake	$\frac{1}{2}$ lb.
Fresh fruit	two or three peaches, apples, or oranges.

The rice ration is usually two-thirds rice and one third barley. The pickles are either pickled plums or mixed vegetables.

THE EQUIPMENT AND WORK OF THE SOLDIER.

The recruit on enlistment receives a free kit; some of the articles the Government replaces as they become unserviceable, others he is obliged to make good at his own expense, but these are sold at cost price, and a careful man can keep his kit in good order at an annual cost of about £1. The kit is divided into the personal and public kit. The former consists of a tunic, a pair of trousers, a khaki drill or serge coat, a pair of trousers of same material, a pair of boots, a cap, two pairs of drawers, a pair of putties, and a cardigan waistcoat. To these must be added such necessaries as two flannel shirts, three pairs of socks, braces, comb, two towels, soap, razor, and brushes for cleaning and polishing. The public clothing consists of a great-coat with cape, a helmet or other headgear, a pair of leggings, and a haversack. Certain articles are also issued free of expense at stated intervals; for the particulars of these, reference must be made to the Clothing Regulations, where they are stated in detail.

In India and other tropical stations light clothing, either white or khaki colour, is used. For other stations abroad, soldiers are supplied before embarkation with such new articles of personal clothing as needed, owing to differences of climate, pattern or scale. Similarly, before proceeding on active service the soldier is supplied with additional articles of clothing according to the circumstances of climate and season.

In selecting the material for soldiers' clothing the chief points to be considered are permeability, durability, and the property it has of conducting and absorbing heat.

Cotton is durable, does not shrink when washed, is non-absorbent of moisture, conducts heat rapidly away, but has the effect of chilling the body if perspiration is present. Hence it is not the material for the dress or undergarments of soldiers.

The disadvantages of woollen clothing are that the material becomes hard and shrinks on washing, and thus loses in part its absorbing properties. Much of this is due to faulty washing, the mistake made being that too often the clothing is coddled and not washed and dried quickly. If care be taken, the tendency to shrink can be much reduced. Often an excess of alkali in the soap used hardens the wool; this, however, is less a factor in shrinkage than washing in very cold or very hot water and failing to dry quickly. Soldiers' shirts are manufactured from a mixture of cotton and wool; this material is lighter and cheaper than pure wool, and is said to be more durable; it does not shrink unduly in washing; there should not be more than 30 per cent. of cotton in the mixture.

The colour of the material has an important bearing on the hygienic value of the clothing, and in regard to the absorption of heat exerts more influence than the material itself. The results of experiments made at Aldershot show that white possesses very slight absorptive power compared to other colours, and, next to this in the scale, grey or pale yellow gives the best results; grey is the best colour for soldiers' dress on service, white is least suited for the field, as it soils so quickly; the khaki drill and serge appears to answer well, and, as regards absorption power, corresponds very closely with grey fabrics.

All clothing should be made to fit loosely, so as to allow free movement of every part of the body, otherwise mechanical work is increased. In the British Army the underclothing consists of shirts, stockings, and flannel belts. The shirts are made of a mixture of wool and cotton. In hot

climates all wool would probably be found a better material; but the collar band should be made of linen to avoid shrinkage, and consequently tightness round the neck. The socks are made of worsted; they shrink badly, and not a little trouble results to the soldier owing to the misfitting and creasing which follows this shrinkage. They are a fruitful source of sore feet. The number supplied to the men might well be increased by another pair. Flannel belts are issued to the men for tropical service to protect the abdomen from chill. We question the utility of wearing these articles during the day; but if once worn they must be continued. To wear these belts intermittently, is attended with great risk, as the chances of chill and consequent enteritis are much increased. These belts should invariably be worn when sleeping under a punkah or in the open air.

The tunic or full-dress coat of the British soldier is close-fitting, and to some extent interferes with the free movements of the chest. If loosely made, it does not give the same appearance of smartness to the men. The coat worn on active service and for every-day work is cut looser, and, moreover, made of either serge or drill. The trouser should be cut full and wide over the buttocks and thighs; a common fault with soldiers is to get this garment to fit almost like a glove. This may look taut and smart, but it is inconsistent with free muscular effort. For active service and every-day work, the trouser is largely replaced by breeches reaching to the ankle, fitting close round the calf; the puttee too is worn with these and also with the trouser. Putties give support to the leg and protect it from bites of insects. These articles need to be put on carefully. In many mounted corps, the puttee is replaced by the gaiter. For the suspension of the trouser or breeches, braces are preferable to a belt round the waist. They give better means of support, and do not compress any part, which a belt invariably must do. This latter is also said to predispose to hernia.

The greatcoat and cape is issued in three sizes, and weighs from 5 lb. 8 ounces to 6 lb. 3 ounces. They are all made double-breasted, but seldom long enough. The cloth is excellent, but it is rather heavy, absorbs a large quantity of moisture, and is difficult to dry. It would be an advantage if the greatcoat could be made of a lighter material, and waterproof.

For service in the field a waterproof sheet is an imperative necessity, to protect against rain or ground moisture. The waterproof sheet should always be used to lie on unless employed to form a temporary *tente d'abri.* Cloth may be made waterproof by the following simple plan:—Make a weak solution of glue, and while it is hot add alum in the proportion of 1 ounce to 2 quarts; as soon as the alum is dissolved, and while the solution is hot, brush it well over the surface of the cloth, and then dry. It is said that the addition of 2 drachms of sulphate of copper is an improvement. Hiller describes a useful method of waterproofing porous materials, as cloaks, &c., by dipping them alternately in a solution of sulphate or acetate of alumina and of soap.

Such articles as sheepskin coats, hoods, gloves, &c., issued for protection against very severe cold, are necessary, and are fully justified by the results following their use.

The head-dress is an important article of the soldier's kit. The essentials of a good head-dress are that it should be light, durable, and comfortable; that it does not press unduly on any part, nor fit too closely on the head. It should admit of a limited amount of ventilation, and its shape should not only serve as a protection to the head, but it should afford as little resistance as possible to the wind. Helmets are now issued to infantry regiments, artillery, and engineers, and also to departmental corps. Bear-skin caps

are worn by the Guards, Highland bonnets and shakoes by Highland regiments, and a seal-skin cap by Fusilier regiments. The infantry helmet weighs $14\frac{1}{2}$ ounces. It is made of cork covered with cloth. The weight of the bear-skin is 37 ounces.

In the cavalry and horse artillery, helmets are also worn, but of a slightly different pattern. They are of excellent shape, but rather heavy. In the Guards and Dragoons the helmet is of metal, and is partly intended for defence. The weight of the Life Guards' helmet is 55 ounces, and that of the Dragoon Guards 39 ounces. Were the helmet made of aluminium, these weights might be considerably reduced. The Lancer cap weighs $29\frac{1}{2}$ ounces, the Hussar $28\frac{1}{2}$ ounces.

In India the same head-dress is worn by all the different branches of the service. Helmets made of bamboo or cork, covered with cotton and provided with pugarees, are now in general use; they are very light, weigh 13 ounces, and afford good protection from the sun.

The boots are supplied from the clothing depôt at Pimlico, and are in thirty-two sizes, made right and left, and weigh about 40 ounces. The sole is wide, and the heel low and broad. The leather has to be of a certain quality, and a number are always cut up and examined before a contract is passed. There must be eight stitches per inch for the upper leather, and the thread must be of a certain strength and well waxed. The great fault of this boot is its hardness and the rough way in which it is finished. Once it is moulded by wear to the shape of the foot, it is an excellent boot. For its preservation, Army Orders direct (1) that soldiers' boots are to be blackened with three coats of ordinary blacking instead of other substances (2) boots or shoes in store are to be dubbed, or have neat's-foot oil applied to uppers at least once in four months.

Weights of the Articles of Dress and Accoutrements, and on the Modes of Carrying the Weights.—These are matters of great importance if good work is to be obtained from the soldier. In the cavalry and artillery, the weight of the accoutrements and equipment is in great part carried by the horse. The cloak, when not worn, is carried either in a roll over the shoulder or in front of the saddle. Including the rider, the load of the average cavalry horse is at least $18\frac{1}{2}$ stone.

Of late years the load carried by the infantryman has been much reduced; in fact, on peace manœuvres he carries little more than his rifle, ammunition, greatcoat and some food; his blankets and valise containing his necessaries are carried for him. The following is the personal kit and equipment for field service of the infantry soldier, as issued in A.O. No. 71, of April 1904:—

	lb.	oz.
Rifle, short, with sling	8	$3\frac{1}{2}$
Sword-bayonet with scabbard	1	$4\frac{3}{4}$
Belt, waist, with four cartridge pouches	1	9
Frog, for bayonet		$4\frac{3}{4}$
Bandolier	1	2
Ammunition (100 rounds)	6	14
Haversack, containing bread or biscuit, emergency ration, fork, spoon, and tooth-brush	2	$14\frac{1}{2}$
Mess-tin and cover, containing some ration	2	$3\frac{1}{4}$
Water-bottle, filled, carriage and strap	3	12
Tin of mineral jelly, pull-through and cover		$8\frac{1}{2}$
Greatcoat, with comforter and a pair of socks	6	6
Head-dress	1	$2\frac{3}{4}$
Jacket, with first field dressing and description card	2	$8\frac{1}{2}$
Trousers or kilt and apron (4 lb. 5 ounces)	2	1
Jersey or cardigan	1	5
Braces		$4\frac{1}{2}$
Shirt, flannel	1	$1\frac{1}{2}$

	lb.	oz.
Belt, woollen, and socks		$8\frac{3}{4}$
Boots, ankle	3	14
Putties or gaiters		$14\frac{1}{2}$
Clasp-knife and lanyard		8
Drawers, one pair	1	$0\frac{1}{2}$
Total	50	$7\frac{1}{4}$

It has been the custom to carry a certain amount of spare kit for the soldier contained in a canvas bag. This, which includes a waterproof sheet, a blanket, and other articles, weighs 12 lb. A recent committee has advised that only the waterproof sheet and blanket be so carried, and that the following essential articles of spare kit—bootlaces, housewife, towel and soap,

FIG. 186A.—"BANDOLIER" EQUIPMENT. FRONT VIEW.

FIG. 186B.—"BANDOLIER" EQUIPMENT. REAR VIEW.

and pay-book—be carried by the man in addition to those given above. If possible an extra flannel shirt is to be carried by the man. The result of this will be an additional load of 1 lb. on the man, or 2 lb. $1\frac{1}{2}$ oz. if he carries the shirt. The canvas shoes now carried for men are deemed a luxury and will be carried for dismounted units to the extent of 5 per cent., and issued on medical recommendation only.

In the cavalry the weight carried seems excessive; the weight of clothing and equipment being nearly equal to that of the man himself. In the case of the infantry soldier, under modern conditions, the load is not excessive though quite enough. Compared with what was carried in earlier times, and even within twenty-five years ago, the load detailed is all in favour of the present-day soldier. Whatever load is carried by the man, the greatest care is necessary to so arrange the weights as not to detract from the man's efficiency or to injure his health. The chief points to attend to are to so adjust the weights that when carried they fall as near the centre of gravity

as possible, and not outside it ; in the upright position, the centre of gravity is between the pelvis and the centre of the body, usually midway between the umbilicus and pubis, but varying of course with the position of the body ; a line prolonged from this centre of gravity to the ground passes through the astragalus just in front of the os calcis. Hence weights carried on the head or top of the shoulders, or which can be thrown towards the centre of the hip bones, are carried easily, being over the gravity centre. If a weight be borne away from this line the centre of gravity is displaced, and, in proportion to the added weight, occupies a point more or less distant from the usual site ; until, perhaps, it is so far removed from this that a line prolonged

FIG. 187A.—" ALDERSHOT 1903 " EQUIPMENT. FRONT VIEW.

FIG. 187B.—" ALDERSHOT 1903 " EQUIPMENT. REAR VIEW.

downwards falls beyond the feet ; the man then falls, unless, by bending his body and bringing the added weight nearer the centre, he keep the line well within the space which his feet cover. In the distribution of weights, then, the first rule is to keep the weight near the centre ; hence the old mode of carrying the soldier's greatcoat, viz., on the back of the knapsack, was a bad one, as it put on weight at the greatest possible distance from the centre of gravity. These principles are embodied largely in the present equipment, which has the advantage of being light and simple. The ammunition is carried in four pouches and in the bandolier. The mess-tin is carried either on top of the greatcoat or under it when this is carried on the shoulders ; or it may be fastened to the waist-belt ; in each case it can be detached without interfering with the rest of the equipment. The most objectionable feature of this present equipment is the bandolier, which when loaded with ammunition presses heavily on the man's chest. The accompanying Figs. 186A and 186B show the present-day marching order equipment.

In spite of its superiority over earlier types, it is probable that this equipment will undergo further amendment and improvement, notably by the substitution of webbing for leather. What line the changes may follow it is impossible to say, but the two following types present features of undoubted merit and are representative of modern military requirements. The great object is to increase the ability to carry ammunition without hampering the man unduly. Figs. 187A and 187B show a soldier wearing an equipment now under trial embodying certain suggestions and improvements put forward by the Equipment Committee in 1903.

A practical trial is also being made of an equipment designed on the

FIG. 188A.—"RUCKSACK" EXPERIMENTAL EQUIPMENT. FRONT VIEW.

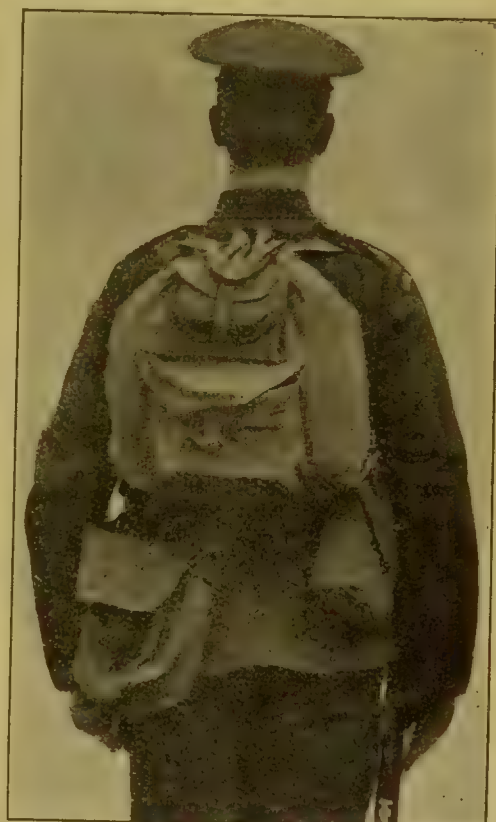


FIG. 188B.—"RUCKSACK" EXPERIMENTAL EQUIPMENT. REAR VIEW.

"Rucksack" principle. This is shown in Figs. 188A and 188B. The idea upon which the rucksack is based is to afford each man a light and serviceable receptacle in which he can carry the whole of his authorised field-kit other than his arms, ammunition, and water-bottle. If circumstances, such as an impending action, render such a course desirable, the rucksack and its contents can be discarded immediately, only indispensable articles, such as arms, ammunition, and water-bottle, remaining to be carried. The rucksack as issued is of the Alpine type, and consists of a rectangular bag of canvas, the approximate dimensions of which are 17 by 17 inches. The mouth of the bag, which is situated at the top, is closed by a running cord, and two pockets are externally attached to the rear face. The lower and larger one is intended to hold the mess-tin, and the upper one the grease-tin and any other small articles. The main portion of the bag carries the great-coat folded or rolled, also any spare or extra ammunition. The rucksack is carried by means of two web straps joined to the top and bottom corners

of the sack. The arms are passed through these straps and the latter rest on the shoulders. When it is remembered how necessary it is for an infantry soldier to have an equipment giving expansive carrying power, either for food, ammunition, or clothing, the utility of this form of valise cannot be called in question.

The advantages of the rucksack are that it can be taken off or put on in a few seconds; further, when marching or when halted, the coat can be unbuttoned from top to bottom without disturbing the equipment. There is nothing hanging about the man to impede his movements, as the load is compact and out of the way. The wearer's arms are free, and his shoulders are not tied down to his belt by straps as is the case in the ordinary form of equipment. The sack can be carried easily over the greatcoat, and itself has a carrying capacity much in excess of any other article of the kind. In packing the rucksack, it is important to keep the weight at the bottom. Let everything be flattened down well; the better a rucksack is packed, the better it rides. The carrying straps should be kept long, so as to allow the weight to rest, so to speak, on the buttocks.

Work of the Soldier.—This is difficult to estimate, but depends on the branch or corps to which he belongs, and, therefore, it cannot be brought under one general description.

The artillery have the hardest work, which comprises mostly cleaning horses, guns, carriages, and stables; the cavalry have very nearly the same amount of work to get through, although their stable duties consist nearly altogether in looking after their horses, but their movements on parade are more rapid, and the distances they cover are greater than the artillery. The infantry duties are mostly confined to drills, marches, and fatigue work in barracks.

All these duties, when not excessive, have a beneficial effect, but when severe and violent work has to be done hurriedly, the soldier is not placed in the same favourable condition to carry out the work as the ordinary mechanic would be; this is largely due to the fact that in the drills the position is more or less strained, while the nature of his dress and equipment adds to the work which a soldier is called upon to do.

With a view to assist in the physical development of the soldier, every recruit is ordered to have a three months' course of gymnastic training. The exercises last for one hour daily and are in addition to his ordinary drill. The training is superintended by a medical officer, who is responsible that it is done properly, and who has the power to discontinue the exercises, if there is any evidence of their acting injuriously, the symptoms indicating the necessity for rest being hurried or difficult respiration, and smallness, inequality, or irregularity of the pulse. The infantry soldier goes through another course of six weeks duration in his first year, but in the cavalry fencing and sword exercise are substituted for it.

During the training the men are carefully examined from time to time and measurements taken to ascertain what effect it has on their physical development. The Regulations lay down that each man's weight must be taken at the beginning and end of each course and oftener if there is any reason to believe that a loss in body weight is taking place, care being taken that the weight is recorded under the same conditions, as far as possible, each time. Men should be weighed in their trousers only; the early morning and before breakfast is the best time.

Admirable as the theoretical intention is of stimulating the physical development of the recruit by setting up drill and gymnastic exercises, there is unfortunately much evidence to show that its practical results are

not free from criticism. The considerable leakage from the army of men who are invalided for disordered action of the heart has for many years been a matter for concern ; careful inquiry indicates that this disability, almost peculiar to the service, is caused by the service, owing to faulty physical training on the parade-ground and in the gymnasium, before the soldier is subjected to any adverse climatic or other non-preventable influences. The faults committed are essentially that the ordinary attitude of attention as inculcated by the drill-sergeant, and many of the postures and exercises carried out in the gymnasium, are absolutely contrary to physiological laws and facts, and involve a maximum interference with the cardiac and respiratory functions. The detailed criticism of the system has been well put by both Davy * and Deane,† whose articles are well worth serious consideration. The attention directed to this subject will probably bear fruit in some much-needed modifications of the gymnastic course, but no course of physical training can hope for success unless planned on a physiological basis and conducted by instructors who themselves have some elementary conception of the two functions of the heart and lungs. That the conditions of service life are the prime and only cause of this irritable state of the heart, in so many soldiers, is emphasised by the fact that it passes off gradually when these men revert to civil life. This view has recently been challenged by Smith,‡ whose facts and arguments should be consulted. He indicates that tachycardia is just as prevalent, if not more so, among civilians wishing to become soldiers as it is among civilians who have become soldiers.

THE HYGIENE OF THE MARCH.

In the consideration of this question a variety of details are worthy of note, some of which are intimately concerned with the acts of the individual, while others are essentially within the sphere of control of the administration, or of superior officers.

Preparation.—In preparing for a campaign or long march, it is important that all cases of disability should be segregated and left behind, since such soldiers are certain to break down sooner or later and become encumbrances to the marching column. Especially does this apply to the detection and elimination of concealed or partially cured venereal disease. Great care, therefore, must be taken that only fit and sound men are permitted to join the columns. The next essential preliminary to every march is to see that the men do not start on empty stomachs. We do not advocate the issue of a heavy or large meal before commencing a march, but rather the consumption of light refreshment, such as tea or coffee with bread or biscuit ; this is particularly desirable when the men break camp and move off in the early dawn, as at such times a little food with a warm drink does much to lessen fatigue and increase resistance to disease.

Time and Length.—The hour of starting on a march and the length of the march are matters upon which any definite rules are impossible, since any movement of troops is largely influenced by weather, roads, and military necessity. The custom in our service is to march in the early morning ; the men are fresh, the air is cool, and the main effort can be

* Davy: "A Contribution to the Etiology of Heart Disease in the Army." *Army Med. Rep.*, 1876, vol. xviii. p. 245.

† Deane: "The Irritable Heart of Soldiers." *Journal of Preventive Medicine*, 1906, vol. xiv. pp. 279 and 337.

‡ Smith: "The Soldier's Heart and the Civilian's." *Journ. Roy. Army Med. Corps*, 1907, vol. viii. p. 1.

completed before the heat of the day comes on. Marches at night are rarely necessary, and our own experiences of marching at night is distinctly unfavourable. Any attempts to march repeatedly at night invariably result in an increase of sickness; except under the stress of military necessity, the loss of sleep and general discomfort occasioned by such night marches may be considered as far outweighing the ordinary advantages to be gained thereby. As to the length of the march, a fair day's effort for infantry under usual conditions may be said to be from twelve to fifteen miles. Of course much more than this can be and has been frequently done, but the above expresses the reasonable limit; a greater average than fifteen miles daily is rarely achieved, except by small bodies of men and for short periods. The severity of the march is not to be measured so much by its mere length in miles, but rather by other factors, such as pace or time in which done, load carried, and formation or position in the column.

Speed and Step.—The rate of speed and individual ease with which a march can be done depends largely upon the size of the command. An infantry regiment will accomplish a fifteen-mile march in a trifle under six hours, but a brigade will need nearer seven hours for the same distance, and a division will require eight or nine hours. The question of individual ease when on the march is further complicated by the fact that the movements of the soldier are, to a certain degree, unnatural and constrained; it is true this is much less so now than formerly, but even so, the weak man has to keep up with the strong, the man of short stride with the one of long, and the very regularity of the step tends to make military marching wearisome. The length of the natural step varies with the height of the individual, but probably should not exceed six-sevenths of the height of the limbs, and, taking the average of a number of soldiers, is about 27 inches. The regulation length of the step in our army is 30 inches at the rate of 112 to the minute. In the French Army the length of the step is 29·5 inches and the cadence 120 per minute; in the German Army the length is 31 inches and the rate 112 to the minute. It is doubtful whether the cadence should be ever increased beyond 120 per minute, since what is gained in number is lost in the reduction of the length of the step. Since the official marching step is somewhat in excess of the length of the natural step of the average soldier, it is advisable to let men make or take their own step; as a matter of fact this is usually done, experience showing that most men can increase more easily the number than the length of their steps. Where weights or loads are carried, the steps must be shorter; this question of the load or equipment has already been considered, and obviously has an important bearing upon the facility with which men will be able to complete a march. At the present time, we do not think the British soldier suffers any serious disability under this heading. The question of formation and position in the column are details of great moment to the individual. On dusty roads, close order becomes particularly trying to the foot-soldier, and for this reason it is a general rule in our service that infantry on the march should preserve a wide front and as open a formation as possible, in order to avoid the effects of crowding; without ventilation through the ranks the air soon becomes very foul.

The Halt.—During marches, regular halts are necessary in order to rest the muscles and to give men the opportunity to ease themselves. In our army, these halts are generally for five minutes in each hour, while on marches of more than twelve miles in length, a halt for half an hour is made usually half-way; prolonged halts are often risky, particularly in hot weather, as the men soon get chilled. The most important sanitary question con-

nected with all halts on the line of march is the need of sanitary police to control and prevent the reckless fouling of the immediate vicinity of the halting-place by men who retire to ease themselves. Too much stress cannot be laid on this point, as its neglect in the past has been the cause of much preventable trouble. The essential need is for the officer in command to allocate areas of ground where the men may resort, and to place picquets or sanitary police over these places to see that the men, using the same, cover up with soil all excretal matter deposited there. The covering of this material with earth need be no elaborate work nor involve any greater effort than the preliminary scratching of a shallow hole with the point of the boot or sword, bayonet or stick, and the depositing of the excreta in this shallow depression, taking care on completion of the act to cover the ordure over with the displaced earth. The personal labour demanded of the individual to carry this detail out is nothing, while the results that would follow its completion in the aggregate are far-reaching. In place of having these halting-places, where regiments and marching columns have halted, loathsome centres of pollution, they would be relatively clean and odourless; while as foci for the spread of infection their capabilities for evil would be relatively small. There can be no doubt that a reform in our practice at halting-places is urgently called for, if only to check or prevent the wholesale fouling of wayside areas where marching columns halt. The remedy is comparatively simple, involves little personal effort, and is limited to an attention to details as explained. It is purely a question of discipline, and until this view of it is realised and put into practice the evil will continue. An appreciation of both the evil and its remedy constitutes one of the most urgent sanitary reforms in our army. Its fulfilment can only follow the awakening of a sense of sanitary responsibility in the officer, coupled with intelligent obedience and co-operation on the part of the man.

Among other details connected with the march and which have an important bearing upon the well-being of the soldier are the use of fluids, tobacco and alcohol, the development of nose-breathing, mental occupation, straggling, and proper care of the feet.

Water Discipline.—All soldiers, especially recruits, are prone to drink as often during the day or on the march as they approach usable water; similarly, a too free recourse to the contents of their water-bottles is a common fault among even experienced men. While arbitrary control over the use of the water-bottle on the march is unwise and impracticable, still it is well to explain to the men the advantages of husbanding their resources and of developing a proper sense of water self-discipline. Much can be done to prevent the sensation of thirst by carrying some small hard object in the mouth, as a pebble, to excite the flow of saliva. To the same end, breathing through the nose rather than through the mouth should be encouraged, while tobacco chewing and to a less degree smoking is inadvisable on the march as tending to increase thirst. The men's water-bottles should invariably be filled with approved water before starting on the march, or they may be filled with unsweetened tea or coffee.* At all halts near water, the quality of the same should be determined by the medical officer, and on his verdict or advice should depend whether the men's bottles are refilled or not at that source. The use of alcohol in any form should be forbidden absolutely on the line of march; if ever such an issue be deemed permissible, it must be so only at the end of the march or when the day's work is over.

* The various modes suggested for securing an approved water for soldiers on field service will be discussed in the following section dealing with the hygiene of the camp.

Mental Occupation.—Few things harass troops on the line of march more than straggling. It is an evil which rapidly demoralises the men and needs to be firmly controlled; its prevention depends upon a careful elimination of the sick, the encouragement and assistance of the tired, and the application of suitable measures to the undisciplined and lazy. To occupy the minds of the men on the march is probably the surest way of preventing fatigue; to this end a band or singing does much to lessen the tedium of the journey. The encouragement of choral singing among soldiers is a matter which deserves every support, and the excellent results following its practice are to be seen in both the Russian and German Armies.

Foot-soreness.—In the conduction of a march, various other conditions may operate to impair the efficiency of the command. The most frequent and notable are the effects which follow exposure to extremes of heat and cold and the results of foot-soreness. The former can be safeguarded by the exercise of intelligence and foresight on the part of the administration, more especially as to selection of time and length of the movement as well as of clothing and equipment to be carried. The proper care of the feet, while rightly within the purview of all officers, is mainly a matter for the individual soldier. Military statistics show that some 25 per cent. of troops on field service sustain more or less injury to the feet as a result of the first few days of marching, and, under the best circumstances and with all precautions, constant marching must be expected sooner or later to render a considerable proportion of an infantry command unfit for duty. Ill-fitting boots and socks, combined with uncleanliness of the feet, are the real causes of this disablement of the marching soldier. The ablution of the feet, at least once daily, should be made compulsory for troops in the field; if facilities for complete washing of the feet are not available, the thorough wiping with a wet cloth, particularly of the toes, answers an excellent purpose in the removal of dirt and grease. Excessive sweating of the feet may be relieved by bathing in $\frac{1}{2}$ per cent. solutions of formaldehyde. For the same purpose, a 2 per cent. ointment of salicylic acid made up with tallow or vaseline is recommended, or a powder made up of the following ingredients:—salicylic acid, 3 parts; starch, 10 parts; powdered talc, 87 parts. These remedies are all well enough, but at best they are but palliatives; the real remedy lies in the provision of a well-fitting boot and a soft, smooth sock to cover the foot. This question is generally well understood and appreciated by the soldier, who realises that for the prevention of injury to the feet by marching three factors must ever receive consideration; these are the elimination of soldiers with badly formed feet, the issue of well-fitting boots and socks, and the enforcement of cleanliness. The ensurement of attention to these details is only to be secured by daily personal inspection by the company or section commanders.

In dismissing the consideration of the hygiene of the march, we would emphasise the fact that marching columns are usually healthy columns, and that, barring foot-soreness, the men composing them show much smaller rates of sickness than do those in more or less permanent camps. The reason of this probably lies in the fact that in the one case men are ever changing their environment, while in the other the possibilities of fouling of environment are in direct ratio with persistence of occupation.

THE HYGIENE OF CAMPS.

All camps may be regarded as so many canvas towns, in which the tents and huts represent so many houses. The selection of a camp site is largely dominated by the facilities which exist for obtaining water, this is particularly so in regard to temporary camps ; but where camp sites are likely to be occupied any length of time, the feasibility of bringing the water to the camp must be as much considered as taking the camp to the vicinity of the water. The selection of camp sites presents no features different from those which have been discussed already in regard to general habitations and barracks, except it be to emphasise the need of choosing areas which are not only dry but clean, that is, have not been occupied recently for other encampments and are not fouled or in any way encumbered with the recent filth of man and animals.

The Camp Space.—Although certain regulations exist as to the manner and plan of laying out various camps, it will be readily understood that these are subject to constant variations owing to physical difficulties connected with the locality. The minimum camp and bivouac spaces allowed for various units or corps, in our own service, are shown in the following table. These, if worked out in terms of men per acre, do not show any excessive density of population on the gross superficies ; but it is only when we come to note the extent of crowding together of men in individual houses or tents that we realise what life in camps really means to the soldier. The dimensions and form of various tents and huts have already been given ; these show that with the full complement of men in a bell tent the superficial space available for each man is not more than 11 square feet. It is true these tents rarely receive the maximum number of occupants, but admitting that is the case, it may be computed that under the most favourable circumstances the average soldier in camp does not get a greater floor space than 20 square feet. Under these conditions, the excessive incidence of some diseases among troops and others living in crowded tents is not surprising. Many experienced officers advocate the disuse of tents for troops in the field and let the men bivouac in the open ; in certain climates this would be sound practice and be attended with the best results, but for encampments in this country, except in the height of the summer, we question whether the total abolition of tents would be permissible. Whatever may be the rule in the future, tents or no tents, it is incumbent upon all to realise the risks attending the crowding of men together in tents, and to do their best to minimise the facilities for direct infection which tent life does so much to foster.

	Cavalry Regiment.	Battery of Artillery.	Squadron of Cavalry.	Field Company, R.E.	Mounted Infantry Battalion.	Infantry Battalion.	Cavalry Field Ambulance.	Infantry Field Ambulance.	Cavalry Brigade.	Infantry Brigade.
Front in yards .	165	75	55	35	200	65	63	120	500	375
Depth .. .	150	150	150	150	150	150	122	200	440	150
Men per acre .	80	76	66	220	65	330	99	94	35	262

All tent walls should be looped up during fine weather, so that the tent area may be dried and disinfected by fresh air and sunlight. Even in cold

and doubtful weather, the sides of the tents should be tied up during the absence of the occupants. If removal to a new camp site or fresh tent area be not practicable, all tents should be struck and their enclosed ground area sunned or aired for a few hours every four days. In a properly arranged camp the intervals should be always sufficient to render the shifting of a tent to a new site possible. Where huts are used, the doors and windows must be opened daily to permit of aeration and the entrance of sunlight, and the roof, if of canvas, should be turned back. The digging up or excavating out of the soil within a tent area should be discouraged as tending to impede ventilation and due cleanliness; if floor-boards are not available, then the ground may be covered with either straw or a tarpaulin, but whatever is employed it must be turned out and well aired and cleaned daily, so long as weather permits. Blankets and bedding must be sunned and aired each day, either by hanging on supports erected specially for the purpose or by spreading on the sunny side of the tent roof; the former plan is preferable, as it allows access of light and air to both sides of the article.

Kitchens and Ablution Places.—The cooking of food in camps presents no serious sanitary problems; at best it must be rough and crude. The most important details which need attention are:—(1) That the kitchens should be located well away from latrines, urine-pits or other receptacles for refuse and garbage. (2) All sullage water must be made to pass into pits from which it can drain away along suitably dug trenches. This waste water is greasy, and if allowed to pass direct on to soil soon makes a felt-like scum which attracts flies. A useful plan is to fill the reception-pits or the upper ends of the drainage channels with coarse brushwood; if the greasy water be poured on to this mass of brushwood, the grease and other organic solids are entangled, allowing the clearer liquid to run freely away. The brushwood, loaded with fatty matter, is conveniently burnt daily and replaced by fresh cuttings. (3) As few remnants of food should be retained in and about camps as possible. This material attracts flies, is very difficult to keep clean, and, in warm climates, rapidly deteriorates. All food remains, particularly if not likely to be utilised in a few hours, should be either burnt or buried. (4) Another important practice is to discourage the men from eating their food in their tents, and also to forbid the storage or retention of food in the tents. This is, admittedly, a very difficult question on field service, when the renewal of supplies is often precarious and the need of economy of what is available an urgent necessity. Still, every effort should be made to reduce the amount of stored food, particularly cooked food, to a minimum. If food must be retained, every endeavour must be made to keep it in closed tins or boxes so that flies may not gain access to it.

The ablution places need to be located conveniently near the men's tents, and the soiled and soapy water therefrom drained away and disposed of on similar principles to those indicated for kitchen sullage water. In standing camps, unless the physical condition of the soil and the gradients are distinctly favourable for a rapid absorption and soakage away of all sullage and ablution water, it will be advisable either to shift the location of the kitchens and washing-places every few days or to collect this liquid in air- and water-tight receptacles. Such receptacles should be placed on raised platforms for the better protection of themselves and the ground beneath them, and should be emptied daily and the contents disposed of outside the camp area. Before being returned to use they should be cleaned and the inside smeared over with a cloth soaked in crude creosote oil.

Disposal of Refuse.—Kitchen refuse and the garbage and hundred and one things which go to make up the ordinary refuse from camps should

never be thrown upon the ground. It should be invariably thrown into special receptacles conveniently placed for the purpose. In camps which are of a temporary nature these receptacles best take the form of pits, but where these are employed the contents must be covered over with at least 6 inches of fine earth each day, the constant endeavour being to protect the material from flies. In more permanent camps all this garbage and refuse should be placed in closed metal receptacles, the contents of which are removed and disposed of daily, as explained for the sullage water. On no account, unless necessity compels, should the solid and liquid refuse be mixed. Carts or waggons for the removal of garbage to the place of disposal should be of special design and capable of preventing any escape of their contents. The casual and too frequent mode of disposal of this waste material from camps by irresponsible civilians, who collect and cart it through lines and encampments without regard to elementary sanitary rules, should be strenuously opposed.

The final disposal of kitchen garbage and camp refuse is a matter of great difficulty, particularly on field service; even in standing camps it is far from easy. The location of the place should always be outside the camp area and placed to leeward of prevailing winds and remote from the source of water-supply. There are two possible methods, burial or burning. The former is suitable for cases where the amount of material to be disposed of is not excessive, but when much refuse is present the labour necessary to dig sufficiently large pits is almost prohibitive. In these cases, destruction by fire is the only means of disposal; in fact, it may be said that burning is the ideal mode of disposal in all cases. Theoretically, this is so, but practically it is difficult to carry out, mainly on account of the natural dampness of the material; in wet weather the difficulties from this cause are much increased. In the field, the methods for the cremation of refuse vary from the use of the company kitchen fire to the employment of specially constructed crematories. Various portable destructors have been proposed and used in camps, probably the best is Horsfall's, but our experience with it has not been satisfactory, mainly owing to its weight and difficulty to move; for fixed encampments it is eminently suitable. Munson * mentions a variety of crematories suitable for camp use, but from our own inquiries we learn that their general utility is not so great as was anticipated. Failing any special apparatus being available for the burning of camp garbage and refuse, ingenuity and common sense must be used as to the best method of effecting the combustion without offence.

Where crude mineral oil is available, its incorporation with the more combustible material constitutes an effective aid for the destruction of garbage. In two camps under our own control, the construction of a simple grate by laying railway rails so as to form a grid or platform on lateral supports was eminently successful in maintaining a brisk fire, fed with camp refuse. In any devices of this kind, the great essential is to secure a draught of air under and through the material to be burnt; and the damper the mass, the greater the need of air. An improvised refuse destructor of a simple nature can be made by digging two trenches intersecting each other at right-angles; each trench should be 9 inches deep and any length from 5 feet. Over the angles of intersection a chimney or shaft is built up of sods of earth, a few pieces of iron hooping or other resistant material supporting the chimney where its walls cross the trenches. A fire can be quickly lighted at the base of the chimney and fed steadily by throwing rubbish and refuse down the

* Munson: *Theory and Practice of Military Hygiene*. London and New York, 1901, p. 395 *et seq.*

top. Assuming the refuse be added with ordinary care and the patency of the draught trenches maintained by judicious raking, an enormous amount of combustible material can be disposed of in a few hours. Such an arrangement needs attention and care, but we have seen them work extremely well in India and at home. Another effective crematory is one mentioned by Arnold.* It consists of a circular pit 3 feet deep and 15 feet in diameter, Fig. 190; the bottom is covered with loose stones to the depth of a foot, and on this a circumferential wall is built up to the height of a foot above the

Fig. 189.—Plan of Improvised Camp Refuse Cremator. From *Journal of the Royal Army Medical Corps.*

ground level, the excavated earth being packed against it to prevent surface water gaining access to the pit, and also to provide a sloping approach for tilting refuse into it. A pyramid of large stones occupies the centre to a height of 5 feet; this is essential to provide a steady draught through the centre of the burning material. Ordinary wood must be used to start the fire, and after it is well burning it can be steadily maintained by adding refuse and garbage. The stones soon become intensely hot and serve to dispose of liquid and damp stuff with great rapidity. This is an ingenious and most effective camp crematory, as we have demonstrated, but it is not of universal applicability; good large stones are a necessity and they are

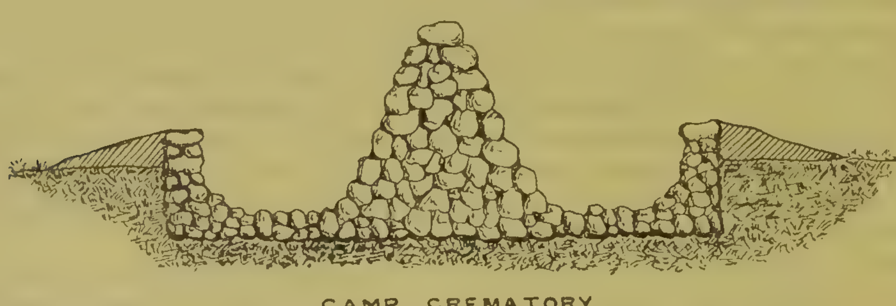


Fig. 190.—Sectional View of Camp Crematory.

not to be found in sufficient numbers in all places. Where they can be obtained, we can testify to the efficiency of this device.

Disposal of Dead Animals.—Closely associated with the question of disposing of camp refuse is that of how to get rid of the carcasses of dead animals. This problem does not crop up during ordinary peace manœuvres, but in time of actual war assumes serious proportions. Here again, two methods of disposal are possible, namely, burial and burning. We may say at once that, unless special furnaces are available, the burning of the carcasses of large animals is impracticable; it is difficult enough to burn the

* Arnold: Article on "Camp Sanitation," *Journal of Association of Mil. Surgeons of United States*, July 1905, p. 15.

dead body of a single animal, but when it comes to having to cope with the carcasses of a dozen or more beasts, such as oxen, horses and camels, the task is quite impossible. The only alternative is to bury, and even then this is far from easy. The time and labour needed to dig a pit to receive the body of a dead ox is appreciable, and when it comes to do the same for some dozen or more similar animals it will be readily understood that few units or commands can do it. What, then, is to be done? To leave the carcass to rot and decompose in the open is to establish a nuisance and general menace to the health of all around—and consequently not permissible. Under ordinary circumstances of warfare, the only course open is to disembowel the animals, bury the viscera as deeply as possible, and to leave the skeletal remains to be disposed of by nature. It is a crude proposal, but the only alternative; the defects of this procedure can, to a certain extent, be minimised by stuffing the eviscerated remains with straw or other combustible material and setting light to it. This will not consume the carcass, but it will do something towards drying it up and lessening the evils consequent on its subsequent gradual disintegration. We do not put this proposal forward as the ideal or desirable procedure; it is merely the least that can be done under circumstances of great difficulty; in many cases improvised crematories can be built up in which the bodies of animals can be burnt, and every endeavour to do so should be made in all camps. The final disposal of *all* refuse matter in camps should be under the direct control and direction of the Sanitary Officer of the command. His powers in this direction must be of the fullest and, moreover, exercised with tact, firmness, and regard only for the sanitary interests of the individuals in his charge.

Disposal of Excreta.—We may now pass to a consideration of how to dispose of the excreta in camps and bivouacs. The proper disposal of this material is vital to the sanitary interests of all, but provided ordinary intelligence be exercised it presents fewer difficulties than might be expected. The moment a camp or bivouac is about to be formed or occupied, the first duty of the commanding officer is to secure and protect his water-supply, and at the same time tell off a special detail for the location and preparation of latrines and urinals. The construction of these necessaries must not be delayed until the tents are pitched and other camp duties have been performed; no matter how temporary the halt may be, the location and completion of these places is an urgent necessity demanding prompt action, and to be supplemented by the detailing of sanitary police to prevent surface contamination of the camp area by casual easement. Certain military circumstances are conceivable when the construction of latrines may be delayed; under these conditions, to avoid surface pollution, some carefully selected spot must be marked off for the reception of dejecta, and sanitary discipline enforced to see that to this spot only do the men resort. At the earliest opportunity all excrement, so deposited, must be buried or covered with earth by the sanitary police. The general location of latrines will depend upon the direction of the prevailing wind and the position of the water-supply; the rule to be observed being, to leeward of the camp and in such a position as no possible fouling of the water-supply can result. The exact position of these places should never be left to the discretion of any officer other than the Sanitary Officer or such officer of the medical corps as may be detailed for sanitary supervision of the command. Latrines should be as far removed from the tents as is compatible with convenience; under ordinary conditions this may be put at 100 yards. The latrines should be placed as far as possible away from the kitchens and other places where food is prepared or stored. The extent of latrine accommodation in camps

will vary according to whether the area is for temporary or permanent occupation; in bivouacs it should be 3 per cent., for ordinary camps occupied for a few days it should be 5 per cent., and in those intended for longer occupation at least 8 per cent. These figures may be taken to represent either yards or actual seats, according to circumstances. The multiplication of latrines is undesirable, as one or two fairly large ones are easier of control than several smaller ones, and soil pollution is also more localised.

In permanent camps, latrine accommodation will best take the form of pail-middens with dry earth, fitted with rough wooden seats, and organised on the plan and principles discussed in Chapter XI. For the reception of urine, iron tubs should be provided, these being placed adjacent to the ordinary latrines for day use, and during the night at selected points convenient for the tents. The contents of these several receptacles will need daily removal in covered and water-tight carts to points well away from the camp area, to be disposed of by burial in the earth. If portable middens, such as pails, are not provided, then the seats must be placed over pits or trenches specially dug. Whatever form the latrine takes, its successful conduction depends absolutely upon rigid adherence to the rule that the excreta must be quickly and completely covered over with earth, and this depends again upon the enforcement of individual sanitary discipline, adequate *personnel*, and competent administrative control and supervision.

For ordinary or more or less temporary camps, the usual latrine is a trench provided or not with a seat. Some 20 feet of trench, 2 feet deep and 16 inches wide, is the common allowance for each hundred men. The great difficulty about all latrines of this kind, no matter whether they have seats or not, is the fact that the front edge of the trench soon gets wetted with urine, and the front of the latrine rapidly becomes a urine-sodden quagmire, the mud from which gets carried back into camp and tents on the men's boots. In the not remote chance of there being one or more undetected cases of enteric bacilluria among the command, the possibilities of infection from this source are not difficult to imagine. To remedy this, our later practice has been not to dig one long trench into which the men can ease themselves, but to dig a succession of short trenches in parallel, across which the user straddles and readily directs both solid and liquid dejecta clear into the cavity, without soiling the sides. Each trench should be 3 feet long, 2 feet deep, and 1 foot wide, and the interspace between each trench not more than 2 feet, preferably less if the nature of the soil permits, so as to preclude the men using the trench otherwise than in the straddling attitude. Our experiences have shown these short trenches to be far cleaner than the old long type; they entail less labour to dig and are more efficiently filled up and renewed. If available, a seat in the form of a stout pole can be laid at right-angles to the trenches, supported on forked uprights. A back-rest may be formed by a similar pole, but is often omitted. Every latrine needs to be surrounded by some form of screen, also roofed in if possible, and the soil removed from the trenches carefully piled to their rear, whence it can be scattered as needed over the deposits.

In all camps where ordinary receptacles are not provided, pits or trenches must be dug for the purposes of micturition. For day use these are best placed within the screen and adjacent to the other latrine trenches. Given a reasonably absorbent soil, the urine soon disappears, but it may happen that such will not occur; in this case, care must be taken to see that supplementary pits are provided, while at all times the exposed urine-sodden soil should be covered at least once daily with clean dry earth to protect it from flies. For night use, when special urine tubs cannot be provided, or when the

day urine-pits are any distance from the men's tents, it may be necessary to dig shallow urine-pits near the men's lines into which they can micturate at night. This is a practice which should be resorted to as rarely as possible, and needs to be zealously safeguarded from abuse; at all times such pits should be carefully filled in at dawn. Urinals can be extemporised easily from empty oil-tins.*

The care of latrines and their proper administration is a most important factor in the preservation of the health of men living in camps or bivouacs, and yet it is a question which too many responsible officers are fain to ignore. No matter where the camp may be, and no matter what type of latrine may be installed, one rule must dominate the successful working of these places. This rule is that all excreta must be covered up as soon as possible with earth, not only for mere purposes of deodorisation but to preclude the access to it of flies. One need not here dwell on the part which these insects play in the dissemination of filth and specific germs to food; it will suffice to say that to any exposed ordure flies will go, and it is our bounden duty to reduce the opportunities of their so going to a minimum. If the excreta deposited in latrines is to be covered over at once with earth, who is to do it? Each individual man covering his own discharges, or some special man or series of men to be detailed for this special purpose? Where ordinary earth-closets or pail-middens are fixed in camps, there should be no difficulty in providing a number of boxes containing dry earth with the necessary scoops, and so enabling each individual to cover his own fæcal deposit. In other camps where the ordinary trench latrine only exists, the situation is not so simple. In the first place, the available soil is less conveniently placed, the provision of scoops in sufficient number is out of the question, and the whole surroundings of the place conduce to a hurried rather than a leisured resort on the part of the individual. Experience shows that it is very difficult to get men to cover their excreta efficiently in these latrines. The only alternative is to place a man within the screen, provided with a spade, and direct him to cover each deposit with fine earth as each depositor moves off. A tour of such duty should not exceed two hours, and might well be limited to one hour. We have known instances where this system has been carried out by corps and with excellent results, but the repugnance and opposition to the performance of such duty manifested by many men suggests that its enforcement in units where the discipline is not of the strictest will be difficult. In these cases what, then, is to be done? The only answer is, enforce discipline and compel the men to cover up their own excreta with earth at the latrines and, moreover, place a sanitary patrol or policeman over the latrine to see that each man fulfils his duty to himself and his neighbour. The care and conduct of latrines, whether in camps or barracks, must be ever regarded as a disciplinary matter, and unless it is so regarded these places will be foci of disease in all places and climates. The condition of all latrines should be verified personally by the orderly officer of the day, at least once during each twenty-four hours. The tendency of the service is to delegate this duty to the quarter-master, who is not an executive officer. This is wrong both in theory and practice and absolutely inconsistent with efficiency: we hope to see the custom discontinued. So soon as latrine trenches have been filled in to within 6 inches of the ground level, their use should be discontinued, earth thrown in and well raised to mark a polluted site. To preclude the access of flies, it is a practical point to see that the earth thrown on to the dejecta is fine and well-crushed soil; the

* This subject is well discussed by McGill: "Water-supply and Camp Sanitation in India," *Journ. Roy. Army Med. Corps*, vol. iii. p. 512.

use of lumps and stones is unsatisfactory, leaving cracks and crevices by which flies get at the fæcal material. On the abandonment of a camp, all latrine trenches must be filled in and the site marked as foul ground.

From time to time a variety of excreta crematories have been suggested, and Munson * speaks enthusiastically of several types. We have tried some and cannot say they have been successful, except when dealing with small quantities of fæcal material. It must always be borne in mind that the combustion of excreta is intensely offensive and readily gives rise to a nuisance, unless carried out well away from tents and buildings. For relatively small quantities of fæculent matter, the forms of steriliser or destructor most practically useful appear to us to be those of Cummins † and Glenn Allen.‡

Water-supply.—The problem of how to supply troops in camp, on the march, or on field service generally with safe or approved water is of paramount importance; it presents many difficulties, but, with trouble and some administrative forethought, we believe many of the difficulties can be overcome. The first duty of the commanding officer on forming or occupying a camp or bivouac is to secure and protect the water-supply. The question of the quality of the water available will be determined by the officer of the medical corps in sanitary charge of the command, and in accordance with his verdict and advice action must be taken as to treatment and general distribution. The protection of the supply from pollution permits of no delay, action must be prompt and thorough, involving the placing of picquets to warn off unauthorised access, and, where only one source of supply is available, to prevent pollution by animals drinking before the men's supply has been drawn. Where the circumstances permit, water for animals should be taken at a point distinct from that supplying men; in the case of running water, the animals' drinking-place must be below that whence the water for troops is taken. When moving into new country, where the nature and quality of the water in wells and streams are unknown, every command should send forward with its advance parties an officer of the medical corps, equipped with simple re-agents, who after making a rapid estimation of its character, should affix an official label or notice indicating whether it be sufficiently good to drink untreated or whether it requires purification before issue.

It will be readily understood that the quality of water available in camps and on field service is liable to vary; in many cases it is sufficiently good to need no treatment, but in many other cases, particularly where surface water from pools or rivers is the only supply, more or less elaborate treatment is required before it can be issued to the men. For the purification of water for soldiers, three possible methods are available:—filtration, heating, and sterilisation by chemicals. Each method presents certain advantages and disadvantages; their general principles have been discussed in Chapter II.; the following observations are directed mainly to details as to their practical application to the circumstances of the soldier in the field.

Filtration.—This is a somewhat elastic term and may range from simple clarification, or the removal of mud and grosser impurities, to true filtration, or the removal of bacteria and other minute forms of suspended matter. Clarification or coarse straining of water can be carried out by a variety of means, such as passing muddy water through canvas, blankets, and other fabrics; the procedure can often be improved by dusting the strainer with

* Munson: *op. cit.* p. 399.
† Cummins: *Journ. Roy. Army Med. Corps*, vol. ii. p. 287.
‡ Glenn Allen: *Journ. Roy. Army Med. Corps*, vol. v. p. 606.

wood ashes or sand, or even alum or alumino-ferric. Chemical precipitants were employed by the Japanese in their late war in the so-called *Ishiji* filter, which took the form of a canvas cone, from which projected arms; these arms or canvas funnels were filled with a piece of sponge and some granulated charcoal. The water, on being passed into the canvas cone, is treated by the addition of two powders. One is a mixture of potassium permanganate with potash alum, and china clay; the other is a mixture of china clay with some chloride of aluminium, a little carbon, and a small quantity of some vegetable extract. These powders act as a precipitant and aid the straining action of the sponges and charcoal (Fig. 191). We have practically tested these filters; in those supplied to us two parts of the first powder were needed to be added for one part of the second. Roughly, 4 ounces of the one and 2 ounces of the other were needed for each 25 gallons of water under treatment. The apparatus clarifies 50 gallons an hour, removing some 90 per cent. of the contained bacteria, and may be considered to be an ingenious device for clarifying water quickly and effectually. This and all other procedures of like nature merely remove the coarser suspended material and cannot be relied on to remove all germs or consequently sterilise the water. To secure this, recourse must be made to the passage of the liquid through some kind of germ-proof filter; this, in the present day, takes the form of a tube or candle made of some close-textured clay on the lines of the well-known Pasteur-Chamberland type, working under a pressure of some 40 lb. on the square inch.

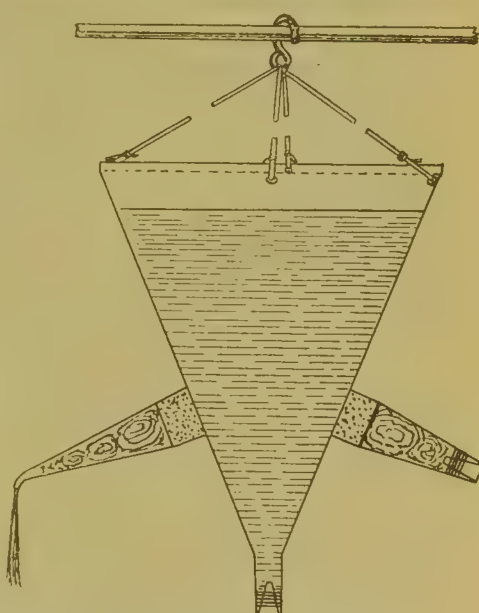


FIG. 191.—"ISHIJI" CAMP WATER-FILTER.

The use of filters of this kind, more or less adapted for field conditions, has been practised in our army for some years. The earlier types took the form of semi-rotatory pumps mounted on a tripod, which forced water through one or more clay filter-tubes. Experience in the field indicated these to present many defects, so much so that we regard them as quite obsolete. The modern filter in our service is constructed on the principle that, while dependence must be made on a hard clay tube to actually remove bacteria, a preliminary clarification of water is essential to save the life of and work thrown on the sterilising filter itself. The best clarifying material for this purpose we find to be a mass of coarse sponges closely packed under pressure in a chamber, while the filter itself is a tube of specially prepared hard clay having a central tube of perforated zinc. Great care is needed to see that all filter-tubes of this nature are free from flaws, more especially at the junction of the metal ends with the clay mass. No filter-tube should be accepted which yields a filtrate under less pressure than 10 lb., and should not need a greater pressure than 40 lb. to give a maximum delivery. Designed on this principle, there are three kinds of field filter, namely, (*a*) filter water-tanks, (*b*) mule filters, and (*c*) coolie filters. Each of these is intended for work under certain conditions.

The filter water-tank is shown in Plate XXII. It consists of an ordinary water-tank on wheels to which are fitted two semi-rotatory pumps, two

sets of sponge clarifying chambers, and two batteries of filter-tubes; each battery contains four tubes, 19 inches long and 2 inches in diameter. In addition, there are two hoses for connecting the pumps with the source of supply, a special metal vessel in which the tubes and sponges can be sterilised by boiling over a camp fire, and a box containing spare filters, washers, screws, nuts, and other essentials. The arrangement of the parts is such that the pump, sponge chamber and filter battery of one side are independent of the corresponding fittings on the other; and, although both series can be worked synchronously, should anything go wrong with one set the other can continue to work. The tank holds 110 gallons of water, and provided the supply be not excessively muddy the cart can be filled, working both pumps, in thirty-five minutes. The water, as it flows into the tank, is merely pumped through the sponge chambers, so that the tank is filled, not with filtered, but with merely clarified water. By changing the setting of the cocks, the same pumps pass the contents from the tank once more through the sponges, then through the filter batteries, enabling it to issue from the swan-neck outlets into the distributing tank as sterile water. The cocks can be so adjusted that, in case of need, the water can be filtered and delivered direct from the source of supply without going into the tank at all, or one pump can be worked in that manner and the other be used for filling the tank. Once filled, the tank can be emptied in half an hour, using both pumps. Our experience with this filter water-tank has been very satisfactory; it is simple to work, efficient, and the tubes or candles are not found to suffer damage. The sponges need washing and cleaning once a week, the filter-tubes must be sterilised by boiling every four days, while the tank itself must be flushed out fortnightly or as circumstances demand. Two trained men are needed to look after and work one of these carts. These men are specially instructed and drawn from the Royal Army Medical Corps. One cart is needed for each five hundred men, or two to an ordinary infantry battalion.

The so-called mule filter is intended for carriage on a pack-saddle, two of these travelling readily on either a mule or pony. In places where wheel transport is impracticable, their value will be great. One of these filters, ready for use, is shown in Fig. 192. It consists of the usual semi-rotatory pump with 15 feet of hosing, connected with a central clarifying chamber full of sponges and from which the water passes into two laterally placed filter cylinders. This apparatus delivers a gallon a minute readily when the water is reasonably clear, but even when filtering very muddy water the delivery does not fall below 54 gallons an hour. The filter is fixed on a wicker-work platform or base which, on being turned upside down, makes the lid or top of a basket case into which the whole fits; the detachable lid is fastened to the main basket by means of screw nuts. In the basket cover are carried two spare filter-tubes and the hosing. The weight of the whole installation when dry is 68 lb., wet it weighs 71 lb. To secure lightness, aluminium is freely used, while the wicker-work is strengthened by bicycle tubing. All detachable parts are fixed by small chains, so that nothing can be lost. The filter-tubes are identical and interchangeable with those fitted in the batteries of the filter water-tank. We regard this pack-saddle filter as an enormous advance on any previous types; it is more portable, gives a greater delivery of water, and is less trouble to work than any we have ever tried. Four filters on two pack animals will suffice for an infantry battalion, while two on one animal will be enough for a cavalry regiment.

The coolie filter is on similar lines to the foregoing, only weighing 40 lb. and presenting but a single filter-tube of standard size. The clarifying

sponges are located in the axis of the filter and not in a laterally placed chamber. For mountain warfare,* where even pack-animals cannot go, these forms of filter should meet a great want. A man can carry one of these filters easily strapped on the back. The delivery from one of them averages 20 gallons an hour.

Purification by Heat.—Ordinary boiling constitutes the simplest method for purifying water by heat, but owing to its extravagant consumption of

FIG. 192.—FIELD SERVICE FILTER, FOR CARRIAGE ON PACK-SADDLE.

fuel, the flatness and insipidity of the water when boiled, and the fact that the treated liquid is too hot for immediate use except as tea or cocoa, this procedure is not generally applicable to the requirements of soldiers in the field. Canney has designed a boiling-vessel which will give 36 gallons of safe water per hour, with an expenditure of 2 pints of kerosene oil; but, as it is estimated that the issue of these apparatus for 10,000 men would entail at least 140 mules for their transport and of the necessary fuel to last fourteen days,* we are forced to consider the scheme unworkable, and to attempt to reach the same end by alternative means, such as by using the ordinary camp kettles. Possibly, in the near future, the soldier will receive a metal water-bottle so constructed that he can boil its contents himself over any

* McGill: *op. cit., Journ. Roy. Army Med. Corps*, vol. iii. p. 516.

camp fire, but until he can boil water for himself in small quantities, it must be done for him in bulk. How to do this economically and rapidly constitutes a difficult problem. The Japanese attempted to do so by the use of water boilers fixed on the frame of an ordinary cart. The general principle of construction appears to have been that of an inner jacket, shaped like an inverted cauldron, with a circular hole for the chimney and another for the stoke-hole, riveted on to an outer cylindrical jacket, so as to form a reservoir for the water between the two jackets and leave a large central space for the fire. Ordinary wood was burnt, and as the capacity of the tank was 15 gallons it took three-quarters of an hour to boil the first filling; subsequent fillings took from twenty minutes to half an hour. We ourselves have been experimenting with portable heaters on this line, but with indifferent success. For fixed camps and posts of position, a simple and convenient apparatus is the Holdaway boiler. We have had some experience of it and found it to work well, 200 gallons of water being boiled in an hour. It burns wood, but being somewhat heavy is unsuited for moving columns.

If water is to be sterilised by heat in any quantity for the soldier, it will be most economically done by means of some form of apparatus designed on the heat-exchange principle. This, as applied to the purification of water, depends on the fact that, with a sufficient area of metallic surface of good conducting capacity and sufficient time, a given quantity of liquid will yield nearly all its heat to an equal volume of the same liquid. In applying this principle to any practical apparatus, the incoming cold water is made to receive heat from the out-going hot water, and in this way the double advantage gained that the fuel required to raise the water to the required temperature is much lessened, and the water issuing from the apparatus is almost as cold as that originally supplied.

There are a variety of these water sterilisers on the market, the better known being that of Vaillard and Desmaroux, that of Hartmann, the Lawrence, the Forbes-Waterhouse, and the Griffith. The two first named, are respectively of French and German make. They both sterilise water, delivering it only some 5° C. hotter than when it entered the apparatus. The great defect of both these types is that they are heavy and cumbersome, in fact a machine capable of delivering 110 gallons of water an hour weighs over a ton; the smaller types are equally heavy in proportion to the amount of water they sterilise, moreover, they are distinctly complicated in design. We have given these apparatus a considerable amount of personal attention and are convinced that for general military needs, certainly in our own army, these continental machines are of little value. It is only fair to say, however, that both the French and German military authorities speak well of their respective types. The other three heat-exchange water sterilisers are all of smaller size, being portable, but delivering relatively small quantities of water. The Forbes-Waterhouse machine is of American make and was well spoken of by their troops in the Philippine campaign. It is also described and recommended by Munson.* We had a number of these sterilisers with our troops both in South Africa and Somaliland, but our experiences with them were not satisfactory. The apparatus is quite portable, weighing 130 lb., but even under the most favourable circumstances yields only 25 gallons an hour: another objection to it is the unreliability of the lamp, which gives an infinitude of trouble. This type is now regarded as obsolete, and the makers, under the name of the Forbes Steriliser, have issued new designs. Their large type of "army water-waggon" is a complete plant,

* Munson: *op. cit.* p. 139.

containing boiler, pumps, filters, steriliser, storage-tank, &c., mounted on four wheels. We have not had an opportunity of trying this machine, but understand that it delivers 300 gallons of sterile water in the hour, and has storage capacity for 150 gallons.

The Lawrence and the Griffith are both of British make and design. The former is packed in a steel tank or case, measuring 3 feet 7 inches by 2 feet by 1 foot 3 inches, and weighs 196 lb. It yields 45 gallons of water an hour, which leaves the apparatus at a temperature of 15° F. above that of crude water. In this machine, as in the Forbes-Waterhouse, the heat is obtained from a lamp burning mineral oil under pressure ; the consumption averages $1\frac{1}{2}$ pints an hour. We have given this steriliser an extended trial and found it to work rapidly and well. Its chief defect is that it is heavy and awkward to handle. For fixed camps, we regard this machine as a distinct advance on its American prototype.

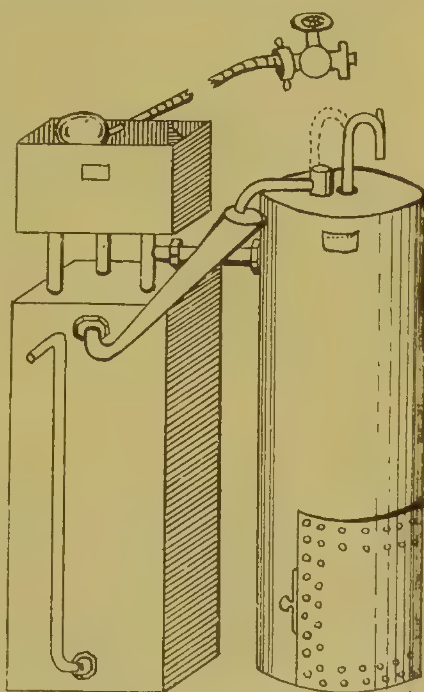


Fig. 193.—The "Griffith" Water Steriliser.

In all the foregoing sterilisers, the water is brought to an actual temperature of 212° F. or upwards. In the Griffith apparatus, the essential feature is the recognition of the fact that an exposure of fifteen seconds to a temperature of 180° F. is sufficient to destroy all disease-producing micro-organisms that are conveyed commonly by water.* The general appearance of this steriliser, when fitted up, is shown in Fig. 193, from which it will be seen to consist of two main parts, namely, a heater on the right coupled to a recuperator or cooler constructed on the heat-exchange principle placed to the left. Above the cooler is a small supply reservoir to which the water can be conveyed by hand or from a suitable tank or water-cart by means of the hosing, the flow of water through this duct being controlled by a screw tap and a ball valve. The heat is obtained from an oil lamp working on the pressure principle, placed beneath the heater within the door shown in the diagram. The two main parts are detachable, so that the whole apparatus packs into two boxes, each measuring 4 feet by 1 foot by 1 foot ; one box with contents weighs 80 lb. and the other 84 lb. This steriliser will yield 60 gallons of water in an hour, the temperature of the outgoing water being 12° F. hotter than that going in. The expenditure of oil averages $1\frac{1}{2}$ pints per hour, or, roughly, half an ounce for each gallon of water sterilised. The vital part of the Griffith apparatus is the valve, which controls the passage of the water from the heater to the cooler, and which cannot be seen in the figure, as it lies concealed within the heater. This valve is so made that it expands or opens only when the water attains a temperature of 180° F., closing automatically when this temperature is not maintained. We have had considerable personal experience of this steriliser and find it reliable, easy to work, and yielding a sterile water. It is far from perfect and is capable of further development, but taking into consideration its size, weight, portability, facility and rapidity of working, its water delivery and consumption of fuel,

* Griffith : "Heat as a Means of Purifying Water," *Journ. Roy. Army Med. Corps*, vol. vii. p. 226.

we consider this to be probably the best form of small apparatus of this kind suitable for military needs.* A later type of this machine, much larger and fitted in connection with a water-tank, gives 350 gallons of water in the hour. This apparatus is mounted on wheels and has a storage-tank for 50 gallons. It carries four gallons of oil fuel, sufficient to run the steriliser for five and a half hours, or one gallon of oil sterilises 480 gallons of water. We have had extensive experience with this larger steriliser and are most favourably impressed with its value and possibilities. Its general design will be understood by a reference to Plate XXII.

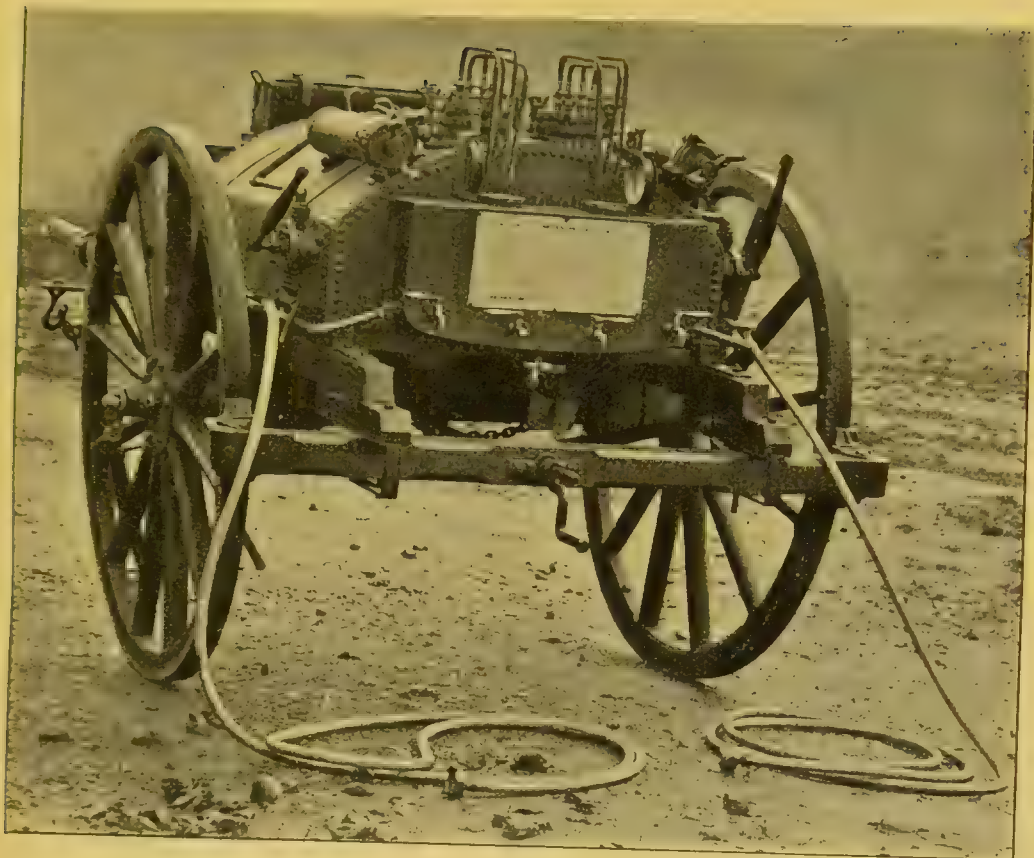
It is difficult to say what part these heat sterilisers will play in the future as means of purifying water for soldiers. In the form in which they are available at present, we think their utility will be greatest in camps where their steady supply with water can be secured ; but a practical trial of the larger apparatus on wheels with troops has demonstrated the feasibility of employing such a steriliser as the means for purifying the water for a brigade of infantry or artillery. The steriliser was located at some convenient source of supply and the ordinary water-carts of regiments or batteries filled from it. In a future development of the machine, no difficulty should be experienced in applying the generated heat as power for pumping water, thereby saving manual labour ; at the same time, its capacity for carrying more oil fuel can be much increased. No difficulty is found when using muddy water, as the steriliser submits all incoming water to a process of rough clarification. Critics have laid stress on the possible inability to supply apparatus of this kind with oil fuel during a campaign ; we anticipate no grave difficulty on this point.

Purification by Chemicals.—To some extent, this question has been discussed in Chapter II. ; looking at the subject purely from the military point of view, we find that a considerable number of re-agents have been advocated for use on field service. Some are reliable sterilising agents, others are not, while many present the further disadvantage of adding taste and colour to the water. As examples of this kind we may mention the "pinking" of water with permanganate of potassium, and Lepeyrère's method of adding a powder composed of the permanganate combined with alum and the carbonates of sodium and calcium. Both these methods act slowly, and even then are unreliable as sterilising agents when water is highly contaminated. In Austria, the use of hypochlorite of calcium in the strength of 0·02 gramme to the litre of water has been advocated, but as any excess over this amount renders the water unpalatable and there are practical difficulties in the way of making it up in tablet form of definite dosage, the objections to its systematic use with troops in the field are consequently great.

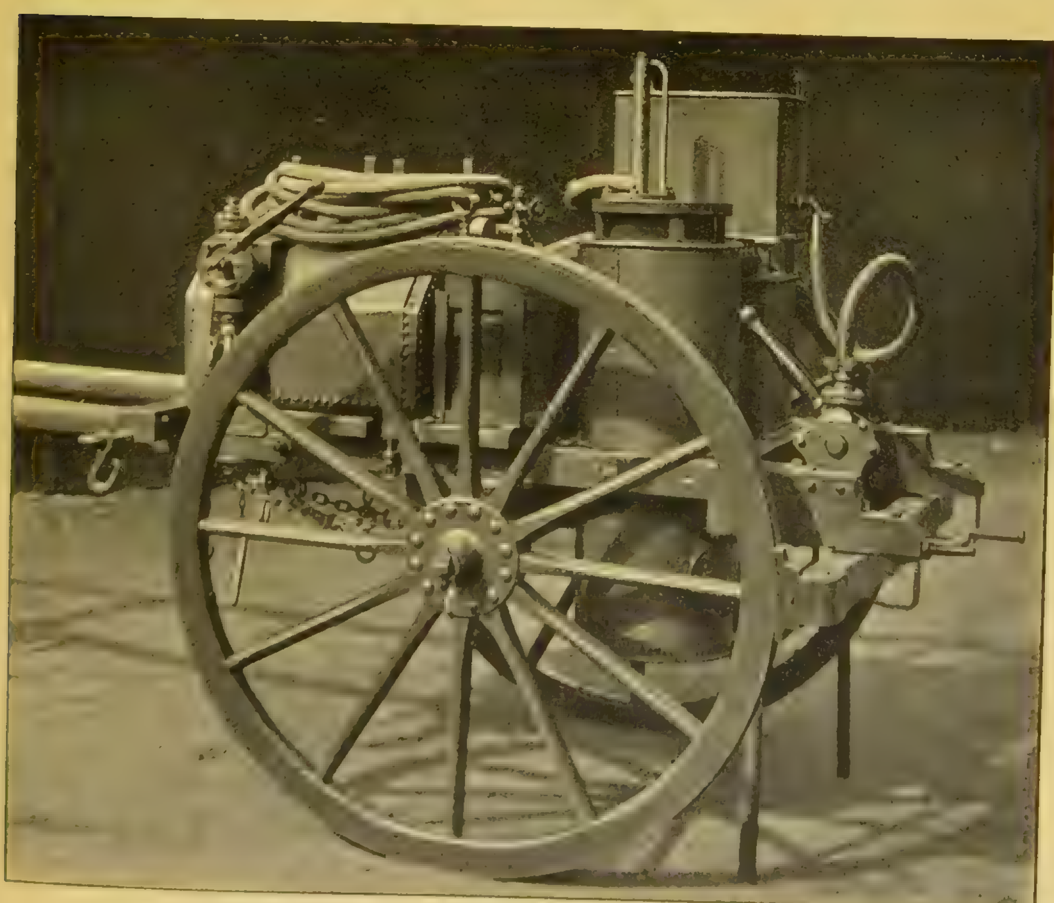
Bergé † advocated peroxide of chlorine, generated by the action of sulphuric acid on chlorate of potash ; whatever may be the merits of this method as a steriliser of water, it is evident that it must be carried out with care and the issue of such a re-agent as crude sulphuric acid to soldiers in the field is obviously impossible. Equally fantastical is Nesfield's proposal ‡ to purify water in bulk for soldiers by means of chlorine liquefied under pressure and stored in lead-lined iron cylinders. He advocates 7·5 c.c. of liquefied chlorine, representing 10 grammes, to be slowly discharged into 18 gallons of water and subsequently dechlorinated by sodium sulphite. We

* Firth: "The Griffith Water Steriliser," *Journ. Roy. Army Med. Corps*, vol. vii. p. 218.
† Bergé: *Proceedings of International Congress of Hygiene and Demography. Paris*. 1900.
‡ Nesfield: "A Chemical Method of Sterilising Water," *Public Health*, vol. xv., 1903, p. 601.

PLATE XXII



WATER TANK FITTED WITH FILTERS.



GRIFFITH WATER STERILISER FITTED TO TANK.

have tried this process practically; it takes quite half an hour to discharge the chlorine if its maximum effect is to be secured and, even then, sterilisation is not absolutely certain. Apart from these facts, practical difficulties exist as to the supply of cylinders of compressed chlorine with an army in the field. Nesfield's other suggestion, to sterilise small quantities of water by means of tablets containing a mixture of bleaching-powder and sodium bicarbonate, is also unreliable; in our experiments, using 1½ grains of bleaching-powder to a pint of water, sterilisation was not secured after an hour's contact.

Schumberg proposed the addition of 0·06 gramme of bromine, enclosed, in a glass capsule, to a litre of water, securing sterilisation in five minutes and then debrominising by adding small tablets of sodium sulphite. This is undoubtedly an efficacious procedure, and was practically tested in the Sudan expedition of 1898. The results were, however, not satisfactory, as the difficulties in the way of carrying large quantities of the re-agents were considerable; we are of opinion, however, that had the organisation been more thorough and the trial of this re-agent been less hurriedly made, the results would have been considerably better. Our own experiences with these bromine globules and debrominising tablets suggests that the process is effective and practicable; we think it has been insufficiently tried.

In 1901, Rideal and Parkes * suggested the use of sodium bi-sulphate as an effective means of destroying pathogenic bacteria in water. They advocated the addition of 15 grains of this re-agent to a pint of water. A somewhat acid taste is imparted to the water by this salt, but such germs as the cholera vibrio, the enteric and dysentery bacilli are certainly killed by half an hour's contact, though absolute sterilisation is not secured. Tablets of bi-sulphate of sodium were issued and tried with our troops during the later stages of the South African War, but the experiment was too hastily planned and too irregularly carried out to warrant any precise decision as to the merits or demerits of the proposal. We have recently tried the method on a large scale with troops, using tabloids each containing 2 grammes of the 70 per cent. bi-sulphate, sweetened with saccharin and flavoured with oil of lemon. One of these tabloids suffices for 1¾ pints of water or the contents of a soldier's water-bottle. The water is sterile in twenty minutes and tastes not unlike lemonade. Having explained their use to the men, no difficulty has been experienced in getting them to use them. The degree of acidity imparted to the water is quite insufficient to render it unpalatable or dietetically hurtful. From the simplicity of the technique involved, we are very sanguine that practical results may be obtained by a further and extended trial of this re-agent by soldiers in the field. For mounted troops, for whom it is difficult to organise a system of filtration or sterilisation of water by heat apparatus, the use of tabloids of this nature seems to offer a reasonable solution of a difficult problem.

Another method which we have investigated and tried depends upon the liberation of iodine by a weak acid from a mixture of iodide and iodate, provided in tablet form. The practical value of this reaction for sterilising waters was first pointed out by Vaillard,† who employed the re-agents in three differently coloured tablets. No. 1 tablet, tinted blue, contains 0·1 gramme of iodide of potassium and 0·016 gramme of iodate of sodium. No. 2 tablet, which is tinted red, contains 0·1 gramme of tartaric acid. No. 3 tablet, which is white, contains 0·12 gramme of sodium hyposulphite. If the first and second tablets be crushed and dissolved in a little water, a brown fluid

* Rideal and Parkes: "The Chemical Purification of Water." *Trans. Epidem. Soc. London*, 1900–1, N.S., vol. xx, p. 62.

† Vaillard: *Archives de Médecine et de Pharmacie militaires*, No. 7, 1902.

containing 0·06 gramme of iodine results; this is sufficient, if added to a litre of water, to destroy its contained micro-organisms in ten minutes. The subsequent solution of the third tablet de-iodises the water and renders it fit to drink. The residual chemicals in the water after sterilisation are about 8 parts per 1000 of sodium and potassium tartrates, 1 part of iodide, and a trace of iodate. This is undoubtedly a very elegant process and we have satisfied ourselves of its efficiency to sterilise heavily fouled water. Excellent as it is, there are grave difficulties in the way of employing it for soldiers. The main difficulty is the fact that the individual soldier in the field will have no facilities to dissolve the 1 and 2 tablets in a little water before adding the resulting iodine solution to his bottle contents. To dissolve them at once and direct in the bottle will not be effective. Apart from this practical detail, the whole technique is too involved to be carried out by any but the most intelligent soldiers. For these reasons we are obliged to regard it as impracticable for general service requirements. For the officer, it affords an excellent means of sterilisation of his water-bottle contents. Recognising the merits of this iodine process, we have endeavoured to apply it to the sterilisation of water in bulk, such as 100 gallons when contained in water-carts. The results have been unsatisfatory, mainly from the fact that there are technical difficulties in the way of making tablets containing a sufficiency of the essential re-agents to sterilise so large a quantity of water. If these can be overcome, there is every reason to believe that a definite system of purifying water in tanks and carts could be organised, working on these lines and with these re-agents. Modifications of this iodine method have been put forward by British makers; they are quite useless for water sterilisation.

Other methods have been under trial by us, notably an electrolytic process, and a precipitation method by means of carbonate of sodium and chloride of iron. Neither has proved satisfactory. We are now trying the use of silver fluoride, 0·005 gramme to the litre; our results so far are promising, and we are not without hope of applying it successfully to the needs of soldiers in the field.

These then are the main facts as to methods of purifying water either actually tried, or suggested for trial, by troops in camp or the field. For all-round utility we are disposed to give the first place to filtration methods, especially in view of the fact that the newer types of filter are free from the defects of earlier apparatus. If it can only be carried out, sterilisation of water by heat is undoubtedly the safest line of defence; and, as explained, the apparatus available for this purpose present no insuperable difficulties in the way of practical utilisation by soldiers in time of war. Doubtless, in the near future, the present types of steriliser will be improved: but, even as matters now stand, sterilisation of water by heat is the ideal method for camps and fixed posts, where installations, working on the heat-exchange principle and subjecting water to a temperature of 180° F. for a few seconds, can deal with considerable volumes of water both efficiently and economically. The utilisation of chemicals for purifying water in camps and in the field is very promising theoretically; but its practical application is full of difficulties. We ourselves have devoted much personal effort to a solution of the water question on these lines, and reluctantly admit that the use of chemical methods by individual troops offers but a slender prospect of being generally applied with success. We do not by this imply that the matter is to be dismissed from further consideration; on the contrary, every endeavour should be made to develop the idea. Even with our present re-agents, chemical methods may be of great use in sterilising water-bottles, tanks and

carts, also for sterilisation of water by tiding men over short periods, when filters cannot be carried or rendered available, but when each man can carry 50 to 100 sterilising tablets. Probably the bi-sulphate of soda offers the best prospect of success on these lines.

Whatever method of purification be employed, its successful application depends absolutely on the dissemination of knowledge as to the object in view among the *personnel* of an army, and the organisation of a system to put it into practice. Regimental and staff officers, as well as the individual soldier, must be thoroughly imbued with the value and necessity of carrying out every detail necessary, and of preventing the use of any water that is not submitted to the process of purification. But this will not be enough, there must be an organised body of men trained in the use and care of all technical apparatus. It was the absence of this trained *personnel* which paralysed our earlier attempts to deal with this question on field service. Highly technical equipment has been issued and handed over in the past to men uninformed, untrained, and often unsympathetic as to their management. Is it any wonder that the utility of this equipment has been seriously doubted? We, in our own army, are now endeavouring to remedy these mistakes; not only is the knowledge as to the object and aims of water purification being sedulously imparted to all ranks, but definite numbers of men of the Royal Army Medical Corps are being trained in the use of all methods of water purification and, as water squads, employed both with units and in camps or fixed posts in the actual supply of purified water to troops. The development of this policy can have but the best results the moment we mobilise and take the field, and we look with confidence to a sensible reduction in the incidence of water-borne disease in our future campaigns.

If the foregoing remarks be true of water purification efforts, it is equally so of general sanitary endeavour. The ever-present need is knowledge and organisation—both are being steadily developed, the former by systematic instruction of all ranks on the why and wherefore of disease prevalence among soldiers, and the latter by the training of selected men from all corps in the principles and practice of general sanitation. Under this system, the conservancy work and general sanitary duties in corps or units in the field army will be carried out by sanitary squads drawn from the units themelves, while in fixed posts on lines of communication the corresponding duties will be done by sanitary squads supplied by the medical corps. Thus, by the twofold line of defence of water purification squads and general sanitary squads, it is hoped to reduce in the future the excessive incidence of preventable disease which has been so marked a feature of all our military expeditions. We cannot hope to abolish sickness and disease altogether from a field force, but it is legitimate to anticipate that organised sanitary effort on these lines will justify a reduction of estimated hospital accommodation for troops in the field from 10 per cent., as at present, to 6. If so, it may be said, truly, the labourer is worthy of his hire.

MILITARY MORBIDITY AND MORTALITY.

If we except the enhanced incidence of disordered action of the heart, the existence of which is denied by some, the soldier cannot be said strictly to suffer from any special disease to which the civilian is not equally liable. In both classes, disease is mainly the result of environment, and in spite of the special nature of their work and mode of life we find that, in peace time

certainly, soldiers suffer from much the same diseases as affect the civilian population living in their vicinity. In attempting to gauge the true incidence of morbidity and mortality among soldiers we must discriminate between the facts as relating respectively to peace and war.

Health of Troops during Peace.—The earliest records regarding sickness and mortality in our own army upon which we can place any reliance are those published intermittently during the period between the close of the Peninsular War and the outbreak of that in the Crimea. From these data we are able to construct the following Table, showing the average amount of sickness and mortality among every 1000 men serving at each of the undermentioned garrisons during the periods specified:—

Garrison.	Period or Year.	Annual Ratio per 1000 of Strength. Admitted as Sick.	Died.	Period or Year.	Annual Ratio per 1000 of Strength. Admitted as Sick.	Died.
United Kingdom:						
Household Cavalry	1830–1836	—	14·5	1837–1846	—	11·1
Cavalry of Line	,,	929	15·3	,,	961	13·6
Foot Guards	,,	830	21·6	,,	862	20·4
Infantry of Line	,,	946	21·6	,,	1044	17·9
Gibraltar	1818–1836	966	22·3	1837–1856	976	12·9
Malta	1817–1836	1142	18·7	,,	1128	18·2
Ionian Isles	,,	1201	28·3	,,	1168	17·9
Bermudas	,,	1310	35·4	,,	1080	35·5
Canada	,,	1097	20·0	,,	950	17·2
Nova Scotia	,,	820	17·8	,,	836	15·1
Newfoundland	1825–1836	1143	37·7	,,	689	11·0
Windward Isles	1817–1836	1903	81·5	1837–1853	1892	62·5
Jamaica	,,	1812	128·0	1837–1855	1371	60·8
Sierra Leone	1819–1836	2978	486·0	,,	—	—
St. Helena	1816–1822	738	25·4	1837–1856	906	12·3
Cape, South Africa	1818–1836	991	15·6	1838–1856	875	15·9
Mauritius	,,	1249	30·5	,,	909	24·0
Ceylon	1817–1836	1678	74·9	1837–1857	1407	38·6
India:						
Bengal	,,	1577	75·6	1838–1856	2047	76·2
Madras	,,	1783	76·1	,,	1741	41·5
Bombay	,,	1451	62·8	,,	2117	60·9
Tasmania	,,	—	—	1839–1856	726	11·8
New Zealand	,,	—	—	1844–1856	529	12·7

Although no elaborate details are given in these early returns, sufficient information is afforded to show how enormous was the death-roll, not only in some of our foreign garrisons, but also at home, during the earlier years of the last century. For further information concerning the sanitary condition of our army at that and a later period we are largely indebted to the Report on the Health of the English Soldiers quartered in England, published in 1858. From the facts given in that report it is evident that the mortality of soldiers at that time was something like two and a half times as great as the mortality of agricultural labourers, and about twice as great as that existing among indoor workers, such as printers. The chief causes of this excessive mortality in military garrisons was phthisis and other pulmonary affections due to overcrowding, defective feeding, faulty clothing, and other unhygienic conditions. The lessons so clearly demonstrated in that historic report were taken to heart, and, thanks to the initiation of a wise policy of sanitary reform, also the amelioration, not only of the housing of soldiers, but of the general conditions of service, a notable change for the better has resulted both in the total mortality among soldiers and in the

non-effectiveness resulting from general disease prevalence. How far this favourable conclusion is warranted will be apparent from a study of our modern statistics relating to the health of the army.

As a comparative statement, the accompanying table has been constructed to illustrate on these lines the varying incidence of disease and its effect upon efficiency in the army for the two years 1859 and 1906, these being the earliest and latest periods for which reliable facts can be obtained. It will be

European Troops.	Ratio per 1000 of Strength.							
	Admissions for Sickness.		Deaths.		Invalided for Sickness.		Constantly non-effective by Sickness.	
	1859	1906	1859	1906	1859	1906	1859	1906
All troops at home and abroad	1120	592·9	18·2	5·52	16·0	11·93	58·0	34·63
United Kingdom	1028	446·8	8·9	2·92	13·0	14·40	60·0	24·86
Gibraltar	948	333·8	7·7	3·97	11·0	7·95	29·0	25·75
Malta	1213	470·8	19·0	2·70	9·0	10·66	52·0	48·65
Egypt and Cyprus	—	1185·8	—	10·79	—	12·50	—	83·03
Canada	545	259·6	10·4	2·99	15·0	13·16	28·0	16·72
Bermuda	537	388·4	13·9	3·76	7·0	15·03	35·0	24·12
Barbados	1050	1114·8	6·3	3·19	—	9·57	—	64·93
Jamaica	1335	793·5	14·4	3·62	4·0	9·06	58·0	85·58
St. Helena	802	225·8	13·0	7·60	—	23·36	36·0	15·50
West Africa	580	1030·2	25·0	4·20	—	21·01	—	59·27
South Africa	923	422·2	11·3	4·28	13·0	7·39	49·0	27·69
Mauritius	1236	671·4	16·1	7·54	11·0	7·54	49·0	45·95
India	1814	871·0	32·2	10·38	12·0	9·39	68·0	51·47
Ceylon	1693	613·3	35·0	10·61	9·0	7·11	70·0	38·08
China	2783	1579·7	59·4	13·21	89·0	13·11	169·0	99·11
Straits Settlements	—	750·6	—	4·49	—	11·99	—	42·19

seen at once that the figures show a marked improvement upon those already given as to the conditions existing before the Crimean War. But bearing in mind that the military service represents a picked male population, and that those unable to maintain the required physical standard are rapidly eliminated, we are hardly justified in accepting them as the high-water mark of sanitary efficiency. Looked at in this light, there is every reason for further serious effort being made toward a reduction of total admissions for sickness and those dying from sickness. On the whole, we are disposed to think the figures for the United Kingdom distinctly good, and if we contrast the mortality at the present time among soldiers serving at home with that of the civil male population of corresponding ages, we find the ratio by no means unfavourable to the soldier. The following statement is on a basis of a thousand males :—

Period	From 20 to 25 years.		From 25 to 30 years.		From 30 to 35 years.		From 35 to 40 years.	
	Civilians.	Soldiers.	Civilians.	Soldiers.	Civilians.	Soldiers.	Civilians.	Soldiers.
1855	8·4	17·0	9·2	18·3	10·2	18·4	11·6	19·3
1906	5·1	2·6	6·3	2·7	6·8	5·8	11·1	8·5

Satisfactory as these figures may be, there is no disguising the fact, however, that the same cannot be said with regard to white troops doing duty in tropical climates. It is not implied that there has been no improvement,

for that there has been; but the statistics suggest that we are marking time rather than advancing. It is conceivable that climatic conditions in the tropics furnish obstacles against a constant reduction in rates proportionate to that which has occurred in home garrisons, still we must not remain content with the present conditions. Much remains to be done, and

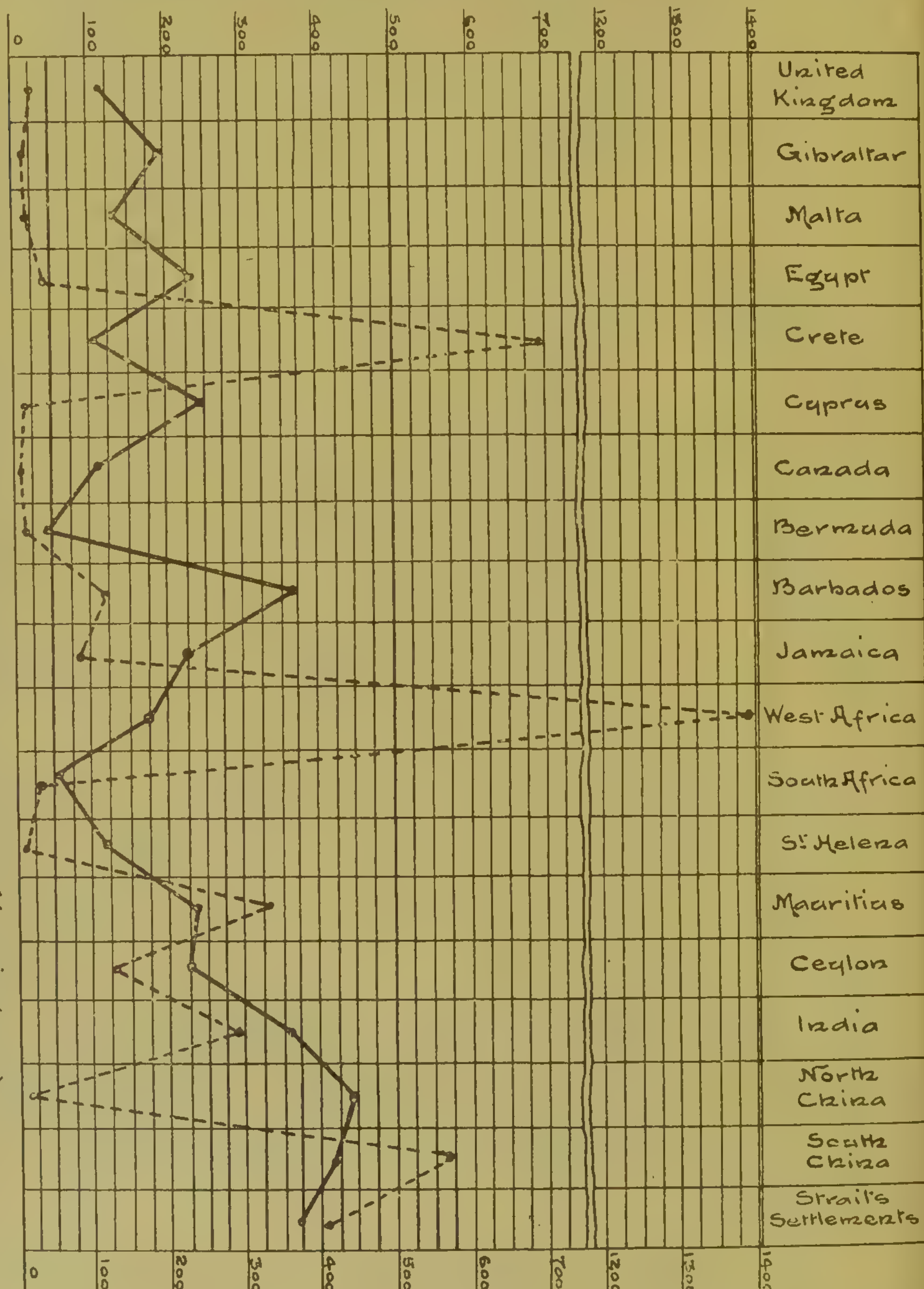


Diagram showing incidence of Venereal (——) and Malarial (- - - -) Diseases per 1,000 of strength, in various Commands. Average of last ten years.

FIG. 194.

there is no reason to doubt that the current rates of disease incidence in more than one of our tropical and colonial stations can be much reduced.

Not only has there been notable sanitary progress in our own army during the past generation, but the same has taken place in those of foreign Powers. In the German Army, the number of admissions to hospital has dropped from 1496 per 1000 in the year 1868 to 783 in 1905. In 1868, the annual death-rate per thousand was 6·9, last year it was only 2·32. Very

much the same story comes from France, where in 1885 the death-rate per thousand was 7·8, while in 1905 the corresponding ratio was 4·58; their

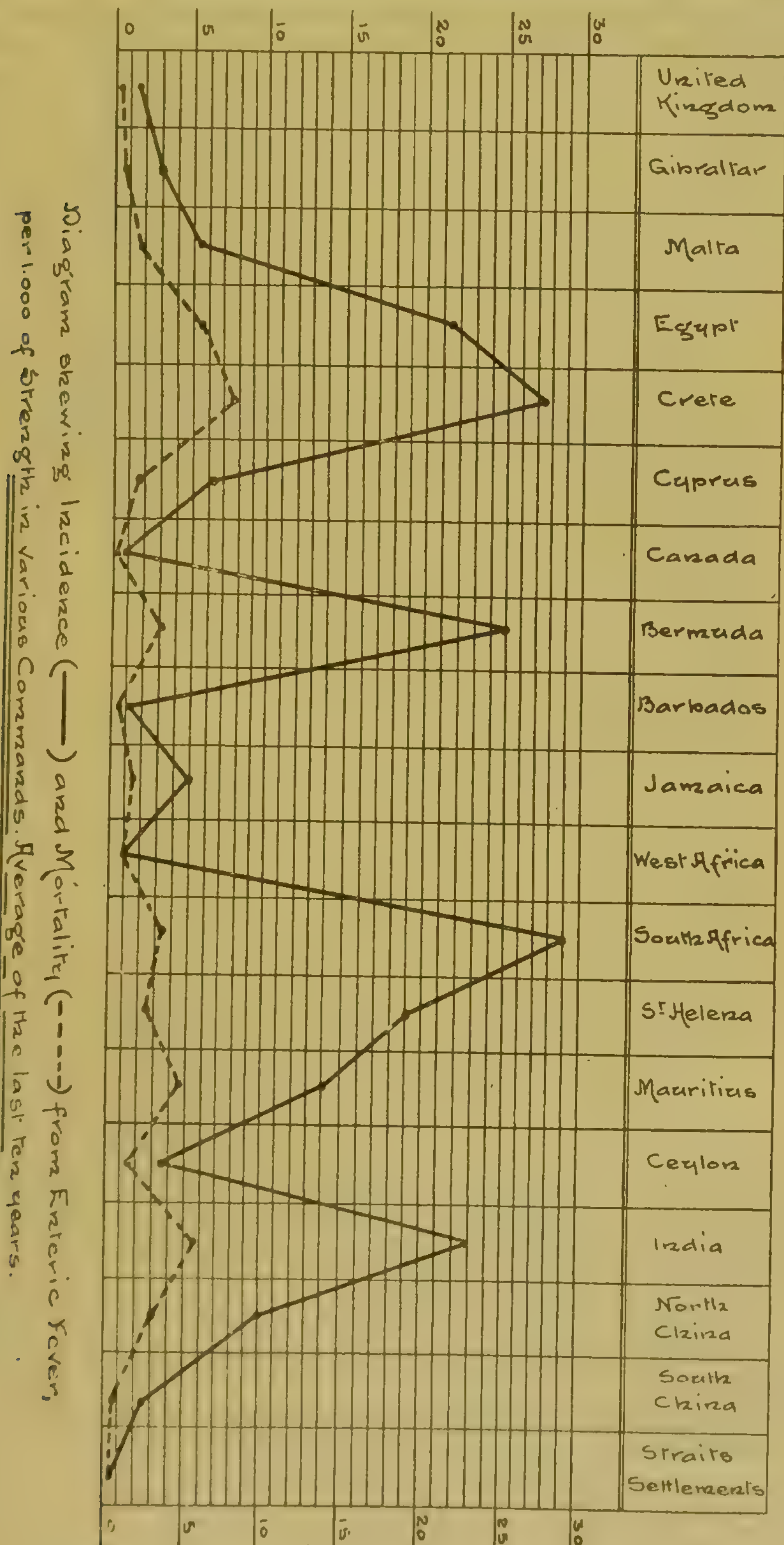


Fig. 195.

admissions to hospital, excluding those treated in infirmaries or quarters, were 177 in 1885 and 156 in 1905. In the Italian Army, the death-rate per thousand was 10·3 in 1885, but only 4·8 in 1905. In the army of the United States the admission for sickness were 402 per 1000 in 1885 and but 136 in

1905, the corresponding death-rates being 6·1 and 3·7. The mortality in the Russian Army at home was 6·32 per 1000 in 1905.

The individual significance of the several diseases, which, taken together, determine the sanitary condition of our army in time of peace will be readily appreciated by reference to the Table on page 939. Venereal affections, malarial fevers (Fig. 194) and digestive troubles, mainly diarrhœa, give the highest admission rates for sickness, but the mortality from these causes is trivial. Enteric fever causes the highest ratio among the deaths (Fig. 195), the next most fatal form of disease being pneumonia and other forms of respiratory trouble. Among causes of invaliding from the service, the first place is taken by various affections of the heart, while a variety of other

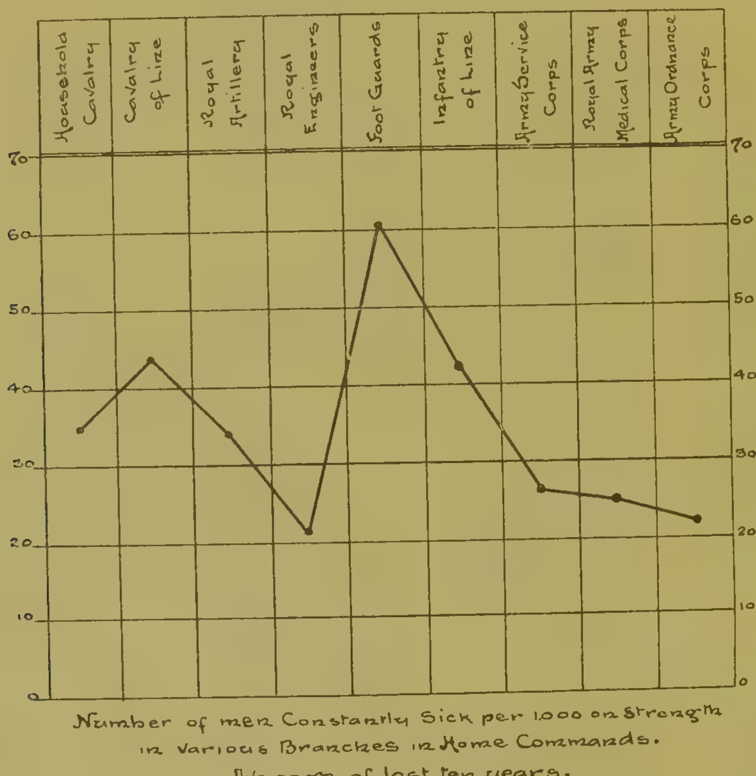


FIG. 196.

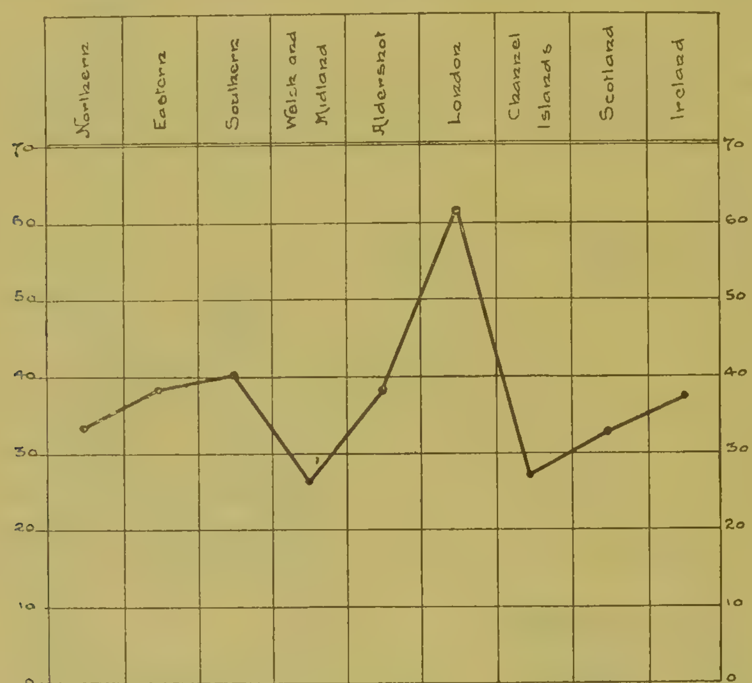
ailments, such as tuberculosis, respiratory diseases, debility and affections of the nervous system contribute in a marked but lesser degree. Judged by the numbers constantly sick, the chief contributing causes to non-efficiency are venereal diseases, digestive troubles, lung troubles, enteric and other continued fevers, rheumatism, and local injuries. It is noticeable that alcoholism is a minor factor in increasing the rates for sickness, deaths, and non-efficiency.

Branch of Service as affecting Health.—It is well known that soldiers of certain arms are more prone to disease than are others; this is usually explained by the character of the duties each is required to perform. We question whether this is altogether adequate. The accompanying diagram (Fig. 196) shows the numbers constantly sick per 1000 in various branches of the service. It will be noted that the highest rate of non-effectiveness is in the Foot Guards, this is due to the greater incidence of venereal disease among them consequent on their being quartered in certain metropolitan barracks. The Cavalry of the Guard, being more busily employed, appear not to be similarly influenced. The figures for the Cavalry and

Diseases.	Average Ratio per 1000 from 1896 to 1905. Admissions.	Deaths.	Invalids finally Discharged.	Constantly Sick.
GENERAL DISEASES.				
Small-pox	·2	·02	—	·02
Measles				
Scarlet fever	6·0	·04	·00	·46
Other eruptive fevers				
Plague	·0	·01	—	·00
Influenza	14·3	·03	·00	·52
Diphtheria	·6	·02	—	·05
Enteric fever	10·2	2·20	·05	1·63
Malta fever				
Other continued fevers	20·6	·07	·04	1·07
Cholera	·2	·17	—	·00
Dysentery	9·7	·29	·08	·73
Yellow fever	·0	·01	—	·00
Malarial fevers	108·2	·25	·19	4·10
Septic diseases	1·0	·07	·01	·07
Tubercle of lung				
Other tubercular diseases	3·3	·62	1·52	·56
Syphilis	9 8	·10	·60	3·62
Gonorrhœa	62·0	·00	—	3·21
Soft chancre	34·5	—	—	2·84
Hydrophobia	·0	·01	—	·00
Scabies				
Other parasitic diseases	19·9	·00	·18	·73
Scurvy	·1	·00	·00	·01
Alcoholism	3·0	·08	·01	·12
Rheumatic fever				
Rheumatism	24·3	·05	·67	1·72
Debility	14·1	·01	1·18	1·01
Other general diseases	5·7	·12	·26	·40
LOCAL DISEASES.				
Diseases of the—				
Nervous system { Nervous	7·7	·26	1·24	·55
Nervous system { Mental	1·6	·03	1·23	·31
Eye	11·6	·00	·98	·70
Other organs of special sense	11·4	·01	1·08	·72
Valvular disease of heart				
Disordered action of heart	12·5	·49	3·89	1·23
Other circulatory diseases				
Bronchitis				
Pneumonia				
Pleurisy	38·9	·94	·63	2·04
Other respiratory diseases				
Digestive	104·8	·81	1·70	4·09
Lymphatic	14·7	·01	·10	1·63
Urinary	2·5	·13	·37	·23
Generative (except soft chancre)	13·5	·01	·29	·76
Organs of locomotion	12·6	·02	1·32	·86
Connective tissue	24·7	·01	·07	1·09
Skin	49·3	·00	·18	2·21
INJURIES.				
General	2·0	·63	·05	·10
Local	92·2	·19	·96	4·16
In action	·4	·00	·33	·04
No appreciable disease	3·5	—	—	·13
Poisons	·6	·07	·00	·03
Suicides	—	—	—	
Cause unknown (refers to deaths only)	—	·01		·09

Infantry of the Line are curiously identical, a fact which militates against the generally accepted view that the mounted soldier has more arduous and risky work than the unmounted. As might be expected, the units showing the lowest non-effective rates are the technical corps, whose men are not only better paid, but also of a higher education and generally superior type.

Locality as affecting the Health of Troops.—The statistics for our army in time of peace are very illustrative of the effects of local conditions of climate, water and environment. Fig. 197, shows the relative amount of sickness existing in the various home commands, while the corresponding facts for the commands abroad are shown in Fig. 198. It will readily be seen how diverse climatic conditions affect the health of the



Number of men Constantly Sick per 1.000 on Strength in the Home Commands. Average of last ten years.

FIG. 197.

soldier. The two diseases which are mainly responsible for these variations in numbers constantly sick are malaria and enteric fever; to a lesser degree the figures are affected by venereal prevalence.

Age.	Per 1000 of Strength. Admissions.	Deaths.	Length of Service in India.	Per 1000 of Strength. Admissions.	Deaths.
Under 20 years	13·5	0·82	Under 1 year	27·2	4·34
From 20 to 25 years	23·4	4·32	From 1 to 2 years	20·7	3·34
„ 25 „ 30 „	11·0	2·34	„ 2 „ 3 „	13·3	3·24
„ 30 „ 35 „	6·1	1·14	„ 3 „ 4 „	13·3	3·02
„ 35 „ 40 „	3·6	—	„ 4 „ 5 „	4·7	1·44
„ 40 upwards	7·6	—	„ 5 „ 10 „	7·8	1·57

Influence of Age and Length of Service on Health.—The importance of these two factors as affecting the efficiency of soldiers, whether in peace or war, is common to all armies. In our own service, where

men serve all over the world, the effects of both age and length of service are most striking. In the garrisons of the United Kingdom, the sick admission rate is highest among men between 20 and 25 years of age, and lowest among men of 40 years and upwards. The mortality rate is lowest among those under 20 years of age and rises steadily in each quinquennial period.

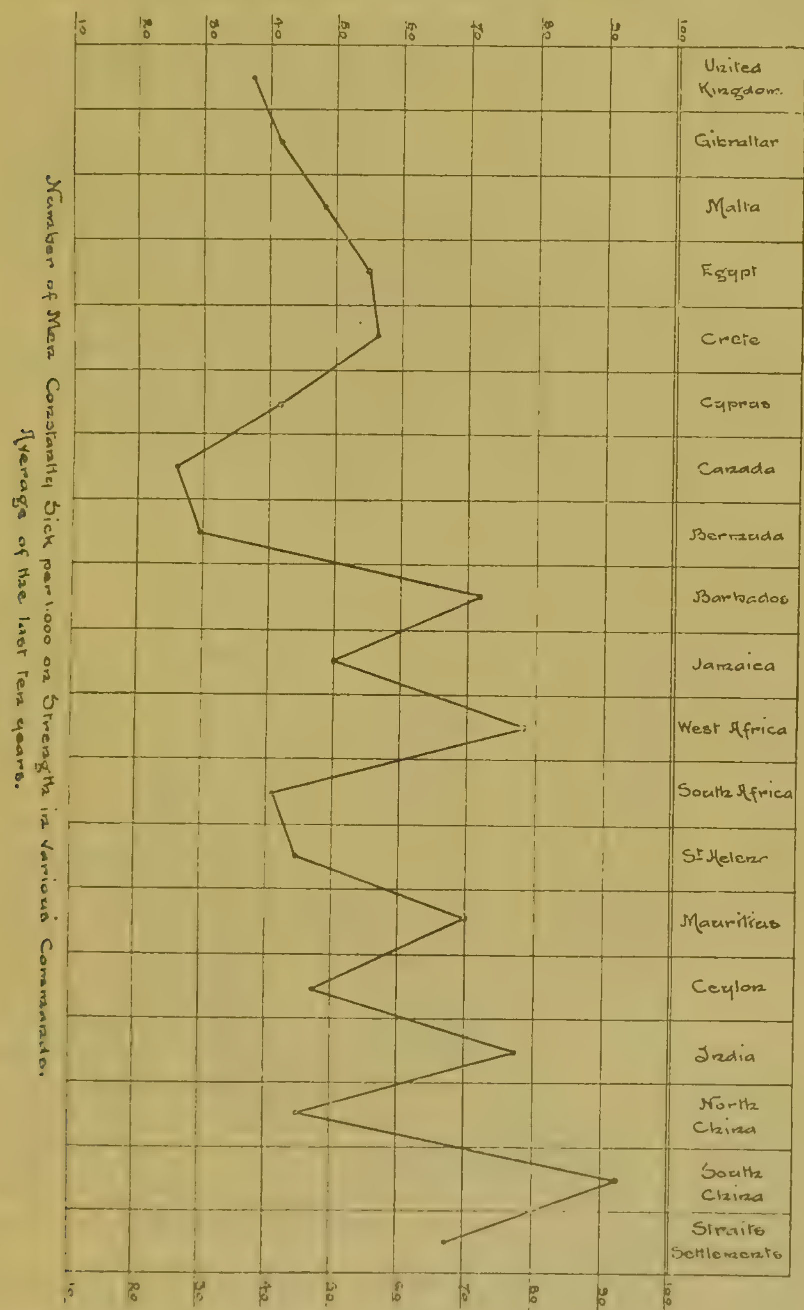


FIG. 198.

The invaliding rate at home is greatest among those of 20 to 25 years, and lowest among those of between 30 and 35 years of age. The most striking effects of age are shown, however, in the incidence of enteric fever; the foregoing Table refers to soldiers serving in India during 1905. The same also brings out the part which length of service in that country plays in the same connection. In the home garrisons, the influence of length of service is equally manifest on the various rates for admission to hospital, invaliding, and deaths. For many years the highest admission rate for all causes has

been among men with less than one year's service, and the lowest among men with ten years' service and more. Invaliding among men at home seems to be highest with those having from three to four years' service; the lowest rates occur among men with between two and three years' service. On the other hand, it is the men with the longest service who show the highest ratio of mortality from all causes; while those with from four to five years of service give the lowest.

Comparative Value of Military Medical Statistics.—We have refrained from loading this article with figures referring to foreign armies, as it is almost impossible to compare with any accuracy the sanitary conditions of other armies with our own. It is true a committee, which met at Budapest in 1894, formulated a plan which overcomes some difficulties, still the physical requirements for recruits are so dissimilar and the regulations as to discharge for disability so diverse that any comparison of the respective figures would be misleading.

Of all the ratios which are given in military medical statistics, the more important which serve to determine the healthfulness or otherwise of an army are:—(*a*) the admissions for sickness, (*b*) the losses by death, (*c*) losses by invaliding out of the service, and (*d*) the numbers constantly sick. A consideration of any one of these rates alone is wholly unreliable; this is particularly the case in regard to the rates for admissions to hospital and for those constantly sick. The latter is obviously dependent upon the former, and both are the direct outcome of the degree of stringency in force as to when a man is taken or placed on sick-report. The admission rate invariably attracts attention owing to its magnitude, but, as explained, it does not of itself imply necessarily a very great prevalence of disease. In a similar way, neither the death-rate nor the invaliding rate alone should be taken as indices of comparison between several commands; the death-rate can be reduced by the removal from the service of those affected with or predisposed to disease, in other words, a high invaliding rate may secure a low death-rate and *vice versa*. The fairest index of comparative non-effectiveness is probably represented by the sum of the non-effective loss as represented by the losses by death and invaliding. Such a figure is shown in Fig. 199; in that chart it is noticeable how high is the invaliding ratio for the United Kingdom; this is due to the elimination of young soldiers within three months of enlistment, consequent on their showing evidence of not being likely to become efficient troops. Virtually, the invaliding rate is the controlling factor in determining the value of the various other rates, while it is itself dependent largely on the physical standard to which the recruit, before enlistment, is required to conform. When we remember, further, that the requirements for discharge are influenced by the rules or customs of each military service and by the personal equation of each medical officer, the difficulties in the way of taking even this ratio, as a standard of comparison between armies or commands, are considerable.

Health of Troops during War.—Hitherto, it must be said, the morbidity and mortality rates of armies in the field have not been very creditable to military sanitary administration, as it is difficult to cite campaigns in which the death-rate from sickness has not been greater than that from casualty; but, on the other hand, it must be remembered that the circumstances of service in the field render sanitary effort, as we understand it in peace, extremely difficult.

The rates for sickness and death in regard to some of our earlier wars are difficult to obtain, owing to faulty statistical methods and absence of reliable records. Perhaps one of the most notoriously mismanaged cam-

paigns in our history was the Walcheren expedition of 1809, in which the mortality from diseases was 347 out of every thousand effective, while only

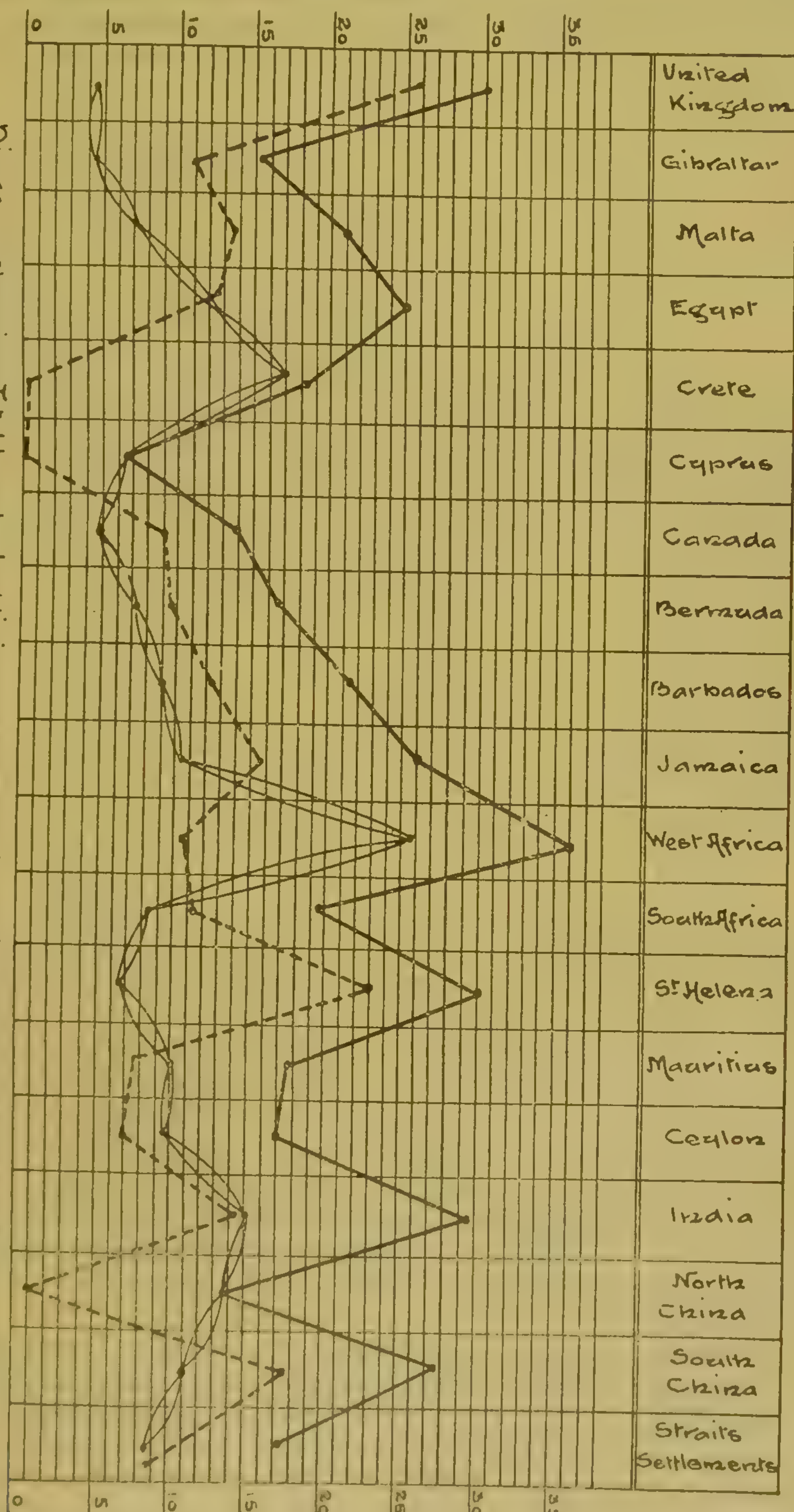


Diagram shewing Total Loss by Invaliding and Death, (——), Loss by Invaliding (- - - -), Loss by Death (⊂⊃), in the various Commands. The curves are calculated per 1.000 of Strength and represent the Average of the last ten years.

Fig. 199.

16·7 per 1000 of strength were killed by the enemy. In the Peninsular War, we lost three times as many men by disease as by the acts of the enemy, and the sick-rate was so great that it was estimated that more than twice the number of the whole army passed through the hospitals during the year. In

the Crimea, our mortality from disease amounted to a ratio of 230 per 1000 of strength, while our losses from wounds were practically 150 per 1000. Confining our attention to more recent experiences, especially in the various tropical and sub-tropical expeditions, which constitute so large a part of our field service, the following Table shows some facts concerning European troops :—

Expedition or War.	Ratios per 1000 of Strength.					
	Admissions.			Deaths.		
	For Disease.	For Wounds or Injuries in Action.	Total.	From Disease.	From Wounds or Killed in Action.	Total.
Ashanti, 1873–1874	474·0	70·0	544·0	16·00	6·0	22·00
Perak, 1875–1876	227·0	1·6	228·6	20·00	1·6	21·60
Zululand, 1879–1880	739·0	12·0	751·0	24·83	1·8	26·63
Afghanistan, 1879–1880	869·9	51·0	920·9	36·03	6·92	42·95
Egypt, 1882	554·0	29·0	583·0	6·06	7·15	13·21
Sudan, 1884	76·2	49·2	127·4	—	31·36	31·36
Nile, 1884–1885	808·6	22·4	831·0	40·01	11·70	51·71
Suakim, 1885	282·9	13·7	296·6	7·87	6·50	14·37
Sudan, 1885–1886	1100·3	46·9	1147·2	29·44	9·82	39·26
Nile, 1889	73·5	3·3	76·8	1·31	0·65	1·96
Ashanti, 1895–1896	49·27	—	49·27	0·56	—	0·50
Chitral, 1895	1530·00	14·0	1544·00	49·39	5·10	54·49
Dongola, 1896	976·60	—	970·60	81·70	—	81·70
Bechuanaland, 1896	531·00	11·0	542·00	28·60	2·6	31·20
Mashonaland, 1896	782·00	53·0	835·0	3·80	15·0	18·80
Tirah, 1897–1898	573·8	25·6	599·4	28·24	2·67	30·91
Nile, 1898	1101·7	56·7	1058·4	36·18	15·67	51·85
China, 1900–1901	1051·7	10·2	1061·9	22·71	2·35	25·06
South Africa, 1899–1901	746·0	34·0	780·0	69·00	42·00	111·06

Owing to faulty methods of tabulation, some difficulty has been experienced in marshalling the figures as to the earlier minor wars in a manner comparable to those of more recent date ; but so far as possible the difficulty has been overcome, and the Table may be accepted as an accurate summary of the facts. It will be seen at once that the degree of disease incidence, as well as the amount of losses sustained from acts of the enemy, has varied immensely : this is not to be wondered at, considering the diversity of conditions under which these little wars or expeditions have been conducted. The most striking feature of these statistics is the marked excess of the sickness admission rates over those for injuries received in action. The disparity is less marked in the corresponding death-rates, but even there it is quite the exception for the deaths from action effects to be in excess of those from disease.

Although most of the diseases occurring commonly among soldiers during peace are met with in war-time, still there is a marked tendency for some to predominate, notably those dependent upon such influences as exposure to climate, pollution of soil or water, and indifferent food. The influence of hostilities shows itself mainly in increased incidence and mortality from respiratory and digestive troubles, malaria, diarrhœa, dysentery, enteric fever and cholera. The precise degree of increased incidence which these diseases display naturally varies according to the climatic and other circumstances under which any particular campaign is prosecuted. This is particularly the case in our own army, which serves all the world over ; but in general terms it may be said that war conditions usually mean a six-fold

increase of such diseases as diarrhœa, dysentery, and enteric fever, as compared with peace-time incidence; malarial fevers are increased about one-fifth, venereal diseases in camp life drop to about one-fourth of the number in ordinary garrison or cantonment; respiratory and digestive affections generally show a slight increase; while injuries, other than those received in action, together with other common disabilities, do not as a rule prevail more than under circumstances of peace.

The closer one scrutinises the medico-sanitary statistics of forces in the field, the more one realises how large a part the so-called preventable diseases still play in rendering an army non-effective. Take, for instance, our recent experiences in South Africa. It is true the precise figures for the three years' campaign have not been fully worked out, still we may say that no less than one-tenth of the admissions on account of disease were for enteric fever, and one-fourteenth were for dysentery, or these two diseases alone were the cause of practically one-sixth of the total admissions and about two-thirds of the total deaths on account of disease; these two diseases also accounted for nearly one-half of the total losses by death from all causes during the war. The sanitary significance of these figures needs no argument. The general principles upon which we can hope to prevent the recurrence of a similar result, in any future field force, have been reviewed and explained.

CHAPTER XXII

MARINE HYGIENE

Marine Hygiene may be defined as the application of the principles of general hygiene to the conditions and exigencies of sea life. These conditions, so far as they affect life and health, contrast markedly with the corresponding circumstances on land. The importance of the subject, and the extent of the interests involved, will be apparent from a consideration of the following statistical facts.

Nature and Extent of the Marine Population.—The total population afloat belonging to this country may be stated in round numbers as being not less than 400,000 persons. It may be divided conveniently into (*a*) that belonging to the mercantile marine, including the crews of fishing-boats registered under both the Merchant Shipping Act and under, the Sea Fisheries Act, and (*b*) that constituting the *personnel* of the Royal Navy.

According to the Annual Statement of the Navigation and Shipping of the United Kingdom issued by the Board of Trade, the number of persons employed in the mercantile marine of the United Kingdom in the year 1906 was as follows :—

Mercantile Marine.	Britishers.	Lascars.	Other Nationalities.	Total.
In sailing-ships . . .	20,315	28	6,365	26,708
In steamships . . .	109,511	39,208	27,978	176,697
In fishing-boats (approximate)	22,167	*nil*	662	22,829
Total . . .	151,993	39,236	35,005	226,234

The Table which follows, prepared from the same source as the foregoing, shows the number and tonnage of sailing- and steam-ships belonging to and registered in the United Kingdom, with the distribution of the mercantile marine population in ships of different sizes.

In the Royal Navy, the total force afloat, corrected for time in the year 1905, was 111,020 officers and men, of whom 68,832, or 62 per cent., were between the ages of fifteen and twenty-five ; 31,085, or 28 per cent., were between the ages of twenty-five and thirty-five ; 8770, or 7·9 per cent., were between the ages of thirty-five and forty-five ; and 2331, or 2·1 per cent., were above forty-five years of age.

Marine Sanitary Regulation and Supervision.—From the foregoing statement of the diverse composition of the general population afloat it will be apparent that the subject of Marine Hygiene is by no means simple, and it is further complicated by the fact that the health of the seafaring community is committed to the care of a variety of departments acting under the authority of different Acts of Parliament.

Classification of Tonnage.	Sailing.			Steam.		
	Vessels.	Tonnage.	No. of Crew per ship.	Vessels.	Tonnage.	No. of Crew per ship.
Under 50 tons	2549	92,130	3·2	1497	41,673	7·8
Of 50 and under 100 tons	1730	118,283	3·8	1306	88,239	9·2
„ 100 „ 200 „	420	61,244	5·5	346	50,692	13·3
„ 200 „ 300 „	66	15,305	6·8	163	40,049	16·7
„ 300 „ 400 „	10	3,525	8·0	165	58,051	21·1
„ 400 „ 500 „	5	2,220	10·0	188	84,063	21·4
„ 500 „ 600 „	6	3,420	11·2	160	88,146	23·3
„ 600 „ 700 „	6	4,092	7·1	145	94,526	21·8
„ 700 „ 800 „	8	6,226	17·6	147	109,652	22·0
„ 800 „ 1900 „	14	12,185	16·7	209	185,393	23·8
„ 1000 „ 1200 „	60	63,821	19·5	218	238,780	25·6
„ 1200 „ 1500 „	172	243,751	22·2	489	683,076	27·2
„ 1500 „ 2000 „	185	335,039	27·0	658	1,198,389	32·1
„ 2000 „ 2500 „	119	264,751	29·4	879	2,019,220	54·3
„ 2500 „ 3000 „	17	47,220	33·6	324	900,632	75·0
„ 3000 and upwards	5	16,602	36·1	519	2,151,412	126·5
Totals . .	5372	1,289,814	—	7413	8,031,993	—

Thus, the Board of Trade have the control of the mercantile marine, including both passenger and emigrant services, and, by virtue of the Merchant Shipping Act, 1894, are able to require that certain provisions as to cubic space, lighting, and ventilation shall be made on all British vessels. Under other portions of the same Act, the food to be supplied to seamen *may* be inspected by medical inspectors appointed for that purpose by the Board.

Under the Public Health Act, 1896, the Local Government Board make Regulations dealing with cholera, yellow fever, and plague, and with other infectious diseases by authority of section 130 of the Public Health Act, 1875, and by the Public Health (Ships, &c.) Act of 1885 can apply sections 120, 121, 124, 125, 126, 128, 131, 132 and 133 of the Act of 1875 to ships. These sections are, by Local Government Board Orders made in pursuance of section 287 of the same Act, enforced by Port Sanitary Authorities (*see* pages 7 and 880).

The *personnel* of the Royal Navy is controlled in all matters bearing on the province of naval hygiene by the King's Regulations and Admiralty Instructions.

The Seaman or Sailor.—If we accept the definition given in section 742 of the Merchant Shipping Act, 1894, the term seaman or sailor includes every person (except masters, pilots, and apprentices duly indentured and registered) employed or engaged in any capacity on board any ship; and further, if we take into consideration their numbers, and the peculiar nature and importance of their calling, the personal hygiene of these men is of exceptional importance to the country. The careful attention paid to hygiene in the Royal Navy testifies to the appreciation of this fact now shown by those officially responsible for the efficiency of that service. The same can hardly be said of the mercantile marine; the seamen of that service are a somewhat variable body, especially in respect of their antecedents. "The sea is too often the last resort of the idle, the careless, and the ne'er-do-well." Why this should be, is difficult to say; but it is probably the effect of a variety of causes, more particularly official and national apathy, want of organisation among owners, and general economic causes.

The seaman should have a good *physique*, though height, apart from

good development, is of no advantage. Excepting it be a somewhat faulty examination of masters and mates as to ability to distinguish colours, there are no physical tests of fitness for service demanded by the Board of Trade in respect of those desirous of entering the mercantile marine. It is otherwise in the navy, where every man or boy desirous of joining is submitted to a rigid physical examination by one or more medical officers. None but promising lads are accepted for the training-ships, while persons of whatever class or age, found to be labouring under any of the undermentioned physical defects or deformities, are, by Article 1154 of the Admiralty Instructions, 1904, considered unfit for His Majesty's Navy :—

(*a*) A weak constitution, imperfect development, or important malformation or physical weakness, either hereditary or acquired.

(*b*) Skin disease, temporary or trivial ; extensive marks of cupping, leeching, blistering, or of issues.

(*c*) Malformations of the head, deformity from fracture or depression of the bones of the skull, impaired intellect, epilepsy, paralysis, or impediment of speech.

(*d*) Blindness or defective vision ; imperfect perception of colours or any chronic disease of the eyes or eyelids.

(*e*) Impaired hearing, discharge from or disease of one or both ears.

(*f*) Disease of nasal bones or cartilage, and nasal polypus.

(*g*) Disease of throat, palate, tonsils or mouth ; cicatrices of neck, whether from scrofula or suicidal wounds ; unsound teeth, or seven teeth deficient or defective in persons under seventeen years of age ; ten defective or deficient teeth in persons above the age of seventeen.

(*h*) Functional or organic disease of the heart or blood-vessels. Deformity of chest, phthisis, bronchitis, hæmoptysis, asthma, dyspnœa, chronic cough, or any evidence of lung disease or tendency thereto.

(*i*) Undue swelling or distension of abdomen ; disease of liver, spleen or kidneys ; hernia or tendency thereto, incontinence of urine, syphilis or gonorrhœa.

(*j*) Non-descent of either or both testicles, hydrocele, varicocele, or any other serious defect or malformation of the genital organs.

(*k*) Fistula of anus, hæmorrhoids, or any disease of stomach and bowels.

(*l*) Paralysis, weakness, or impaired motion or deformity of either extremity, including varicosity of veins, especially of the leg, and distortion or malformation of hands, feet, fingers, or toes.

(*m*) Distortion of the spine, of the bones, chest, or pelvis, no matter whether from injury or disease, or from constitutional defect.

The Vessel or Ship.—Section 742 of the Merchant Shipping Act, 1894, defines the term " vessel " as including any ship or boat, or any other description of vessel used in navigation. Similarly, " ship " includes every description of vessel used in navigation not propelled by oars. Boyd, quoted by Armstrong, says that " the criterion as to whether a vessel falls under the category of ship, is whether the vessel be one whose real habitual business is to go to sea ; if so, though propelled by oars as well as sails, it is a ship within the meaning of the Act. If she does not go to sea at all, she is not a ship in this sense."

The simplest classification of ships is into (*a*) men-of-war, (*b*) merchant ships. These classes can be further divided into groups according as to whether they are either wooden or iron ships, or whether they are steamships or sailing-ships.

Men-of-war, in the present day, are practically all iron ships and also steamships ; they comprise battleships of the first, second, and third class ; first-, second- and third-class cruisers ; sloops ; gunboats ; torpedo-boats ; torpedo-boat destroyers ; troopships ; storeships ; and stationary harbour ships.

Merchant ships are naturally divided into steamers and sailing-ships. Steamers may be further classified into passenger ships, trading or cargo ships, trawlers or fishing vessels, whaleships, cattleships, and colliers. The majority of these are built of iron and propelled by steam.

Sailing-ships, in the present day, are practically limited to the conveying of cargoes only, or to the carrying out of special industries, such as fishing,

sealing, or whaling. Any precise classification of sailing-ships is founded primarily upon their rig. For example, we have full-rigged ships, brigs, brigantines, barques, barquentines, schooners, topsail schooners, cutters, yawls, barges, luggers, ketches, and other small vessels.

A full-rigged ship has three masts, each fitted with topmast, topgallant-mast and royal mast, all being square-rigged.

A barque is a three-masted vessel, the two foremost being square-rigged as above, the hindmost, or mizzen, having only topmast with gaff sail.

The barquentine resembles the barque in having three masts, but only one of them (the foremast) is square-rigged.

A brig is a square-rigged, two-masted vessel.

The brigantine has also two masts, but only one, the foremast, is square-rigged, the other, or aftermast, carrying a mainsail or boomsail, with topmast and gaff topsail.

A schooner may be either three- or two-masted; the lower masts being long with short topmasts and no yards, and carrying mainsails and gaff topsails only.

The topsail schooner is a two-masted vessel with long lower masts, the foremast having a loose square foresail, the aftermast having mainsail and topmast, &c., as in a brigantine. Some topsail schooners have three masts; in them the foremast is the same as in the foregoing, the two aftermasts having mainsails and gaff topsails.

A cutter is one-masted with running bowsprit, carrying jib, foresail, and boom-mainsail.

Sailing- and steam-ships may also be classified according to their build or arrangement of decks. Thus we may speak of one-, two-, or three-decked vessels; or, if lightly built, of spar-decked ships. Other terms in common use are flush-decked, well-decked, hurricane-decked, shade-decked, awning-decked or shelter-decked; all these expressions have reference to the character of the decks and the structures upon them.

While the *rig* of a ship has practically no relation, beyond that of general size, to its general hygienic character, it is far otherwise with the *build* or construction. Ventilation becomes more and more complex in proportion to the number of compartments into which the ship is divided either vertically or horizontally, transversely or longitudinally. These conditions vary considerably according to the material of which the vessel is constructed. Ships are built either wholly of wood or metal, such as iron or steel, or they are composite, that is, composed partly of wood and partly of metal. The principal facts connected with the construction of both wooden and iron ships demand some detailed reference.

Construction of Wooden Ships.—The frame or skeleton of a wooden ship consists principally of the following parts:—keel, keelson, stem, sternpost, timbers, planking, beams and stanchions.

The *keel* may be regarded as the backbone of a ship, and runs the entire length of the bottom of the vessel. It is usually, in wooden ships, made of elm, square in section, and consisting of a number of segments connected together by a joint or splice. The keel in front terminates in the *stem*, with which it forms an angle of from 80 to 100 degrees; behind it joins the *sternpost*, to which is attached the rudder. To the keel at regular intervals, and curving outwards like the ribs of an animal, are fixed the *timbers*; those in the front, or bow, of the ship are called "cant timbers," those aft of the cant timber are the frames. To the timbers are attached the inner and outer *plankings*; these generally run horizontally the entire length of the ship. These inner and outer plankings constitute the "skins" or walls

of the ship. Between the skins in the intervals of the frames is a space in the walls, closed at the top by a covering board and extending downward to the bottom of the vessel, where it ends in the *limber* or *bilge*, a longitudinal channel parallel to, and one on each side of, the *keelson*—a kind of inner or upper keel. In order to strengthen the walls, the "skin spaces" are

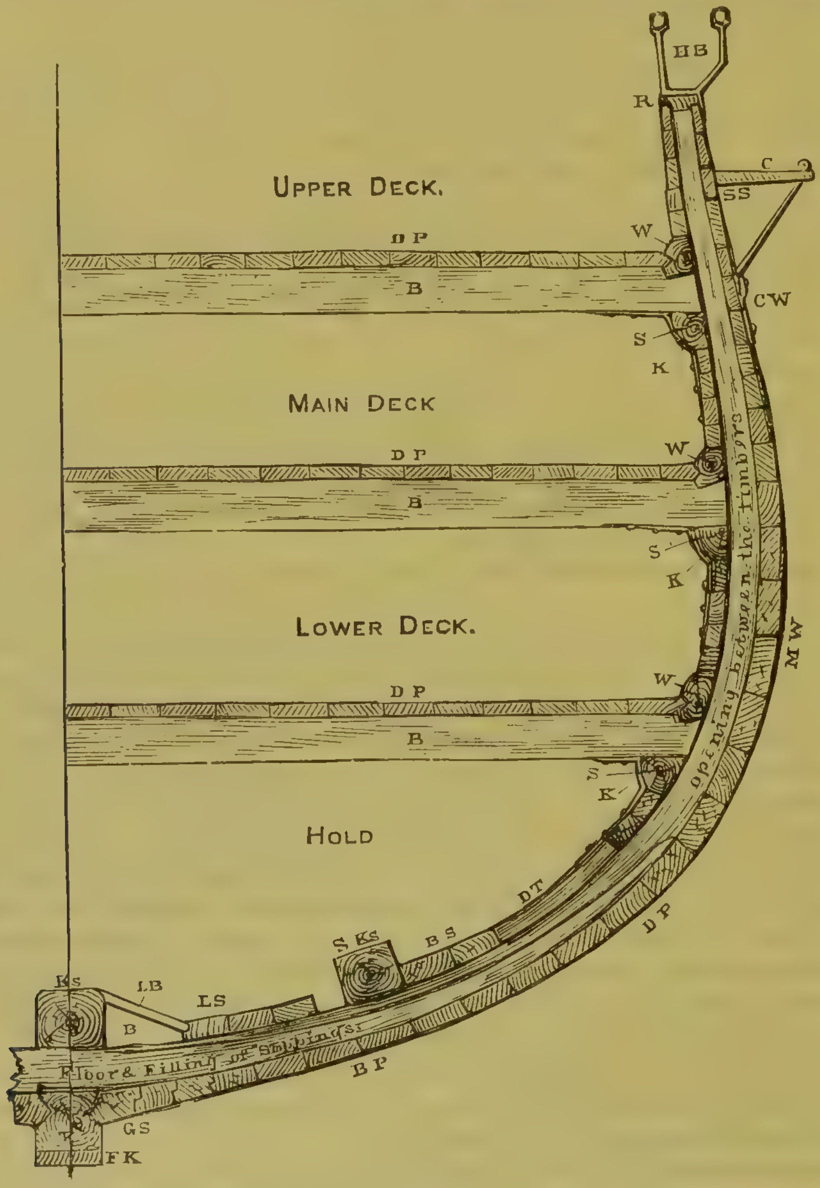


FIG. 200.

F.K., False keel; K.S., Keelson; B., Bilge; L.B., Limber board; L.S., Limber strake; S.Ks., Sister keelson; B.S., Binding strakes; D.T., Diagonal trusses; G.S., Garboard strake; B.P., Bottom planking; S Shelf-piece; W., Waterway; D.P., Deck planking and diminishing plank externally; K., Iron knee; B., beam; R., Rough tree-rail; H.B., Hammock berthing; C., Channel; S.S., Sheer strakes; C.W., Channel wales; M.W., Main wales.

often occupied by "fillings" of seasoned wood, first introduced by Seppings and often called after his name. The outside planking of a ship's wall is known by certain technical names, varying with different parts of the vessel. Thus, the term "garboard strake" is applied to those planks next to the keel; the planks from the garboard strake to the bulging portion of the

ship's side are called the "bottom planking"; the name "main wales" is given to the planks at the water-line; those near the main deck are called the "channel wales," while those on the bulwarks are spoken of as the "shear strake." These technical terms and parts of a ship's structure will be readily understood by a reference to Fig. 200, which gives a midship section of an ordinary wooden ship.

In addition to the foregoing special structures, the framework of a wooden ship is made up of *beams* or substantial pieces of timber running horizontally across the vessel from timber to timber. These are secured to the timbers above and below by structures known respectively as *water-way-pieces* and *shelf-pieces*, and which run from end to end of the ship, forming a kind of internal horizontal strengthening band. The waterway-pieces are similar in structure to the shelf-pieces, and are so called because their upper and inner surfaces are so shaped as to form gutters to receive the drainage of the decks. The *decks* practically consist of planking laid across the beams in a fore-and-aft direction. In the middle line of the ship the beams rest upon *stanchions* or pillars, the lower-deck stanchions springing from the keelson, while the upper ones rise from deck to deck.

Construction of Iron or Steel Ships.—These vessels have more or less the same essential structures as wooden ships, but all are made of metal. In general principles the construction of an iron ship is the same as that of a wooden one, but there is this essential difference, that in iron ships the keel and ribs are not such prominent structures as in wooden vessels, and that the strength of the whole ship depends as much upon the quality of the metal and upon the rigidity with which the various parts of the framework or shell are secured together as upon the strength of such individual parts as keel, ribs, beams, &c.

Perhaps the most conspicuous feature of iron and steel ships is the subdivision of their hulls into a number of watertight compartments and the provision of cellular double bottoms or water-ballast tanks. These arrangements are obviously great safeguards against accident, and are met with in all modern men-of-war, as well as in the better class of mail and passenger steamships. In purely cargo vessels, watertight bulkheads are not very generally provided, as they interfere with the loading and unloading and the storage of bulky articles; the greater number of such vessels, however, have double-bottomed compartments, which serve not only as a safeguard against flooding in the event of the shell being penetrated, but also as wa er-ballast tanks when the vessel is empty or loaded with a light cargo.

Interior Economy of Ships.—With regard to the comparative salubrity of the different kinds of ship, there is much to be said both for and against sailing- and steam-ships or in respect of wooden and iron or steel vessels. Sailing-ships appear to be more liable than other vessels to accidents by loss of men overboard and the general danger of the sea. On the other hand, accidents connected with machinery, scalding, &c., and the sickness resulting from continuous work in high temperatures, are characteristic of steamships. From a mere health point of view, the substitution of iron or steel for wood in the construction of ships has rendered easier the cleansing and disinfection of vessels, but has made it more difficult to maintain a suitable temperature in cold weather and to prevent excessive heat in the tropics; to these disabilities of metal ships must be added the disagreeable effects of condensation on metal surfaces from moisture-laden air between decks.

When compared with vessels of the merchant service, men-of-war have both advantages and disadvantages. Though the crews of men-of-war are,

in most respects, exceedingly well cared for, the proportionately large numbers of men on board and the general construction of the ships imply crowding and defective ventilation. Of late years in the mercantile marine, the tendency has been in the direction of undermanning, with of course an attendant increase of cubic space per head. The forecastles of these ships are, as a rule, more easily and possibly better ventilated than the crew's quarters in a battleship. Passenger and emigrant ships are quite a class of their own, and vary largely from the magnificent liners, with full accommodation and every luxury, to the dark, dirty, overcrowded emigrant ships characterised often by discomfort and cheerlessness. Of this latter kind of vessel the most objectionable are the few carrying both emigrants and cattle. The same difficulties met with in these ships occur sometimes in naval transports carrying cavalry.

From a sanitary point of view, the most important features of the interior economy of ships which demand special reference are the *bilge*, the fore and after *peaks*, the *stokeholds*, the *lavatories*, the *closets*, the *forecastle*, *deck-house cabins* and *general accommodation* for crews and passengers, the *ventilation* and the *heating*.

The Bilge.—In marine language this term has a double meaning. By a shipbuilder it is applied to the curved part of the outside and bottom of the vessel, below the waterline, which bulges. By a sailor it is applied to that cavity or cavities in which offensive liquid, known as bilge-water, collects. In this latter sense only is it used in this article, and constitutes, therefore, that part of a ship to which all internal drainage gravitates. From what has been detailed already regarding the construction of ships, it is apparent that, in wooden vessels and such iron ones as have a keelson, the bilge is a double channel. In men-of-war and other iron vessels without a keelson the bilge is merely that portion of the upper surface of the inner skin about the median line on which drain fluid naturally collects. Closely connected with the bilge is the *main drain;* this is a large pipe running nearly the whole length of the ship, and may be placed either above or beneath the inner bottom of the vessel. This pipe receives the drainage from the bilge, and is further connected with the bilge-pumps, and also receives any water which may have gained access to the bunkers.

Fore and After Peaks.—These are spaces right forward and right aft; and next to the bilges, perhaps, the most insanitary parts of a ship. These places are separated from the hold, &c., by bulkheads; but are frequently in a most foul condition, and in the case of the fore peak in small ships materially affect the air of the lower forecastles, where the crew are housed, and through which alone entry is gained to it. The hatch rarely fits tightly, in spite of the Board of Trade's regulation, which requires it to be fastened down on to a ring of rubber or other elastic material, hence any effluvium passes readily into the crew space. Where there is sufficient beam for the purpose, the forecastles should be separated by a passage-way leading to the fore-peak hatch, and any spare space so left utilised as a store for oilskins or other wet clothing, which it is obviously desirable to keep out of the forecastle. Where the beam of the vessel will not admit of this arrangement, the hatch might be placed in the middle line and a corresponding hatch placed in the top-gallant deck; these two hatches being connected by means of a wooden casing.

Stokeholds.—In steamships the engine-room and boilers are usually placed amidships, extending downwards to the floor, and separated from the hold between decks by bulkheads, thus preventing the free circulation of air from end to end of the vessel below deck. From a health point of

view, important parts of such ships are the stokeholds. These places are situated at the bottom of the ship, deeply below water, and from them the furnaces are coaled. In the smaller vessels there is only one stokehold, but large ships have two or more. In these parts of the ship the heat may be, and is often, excessive. For economy of space, the stokehold is rarely made wider than is absolutely necessary, often not more than from 8 to 10 feet; the stokers, therefore, have to work in a sort of deep well, exposed to great heat from the furnaces, and from which they are unable to withdraw whilst on duty. The air at the bottom of the stokeholds tends to become very foul, while the temperature not unfrequently recorded is from 115° F. to 140° F. In a properly ventilated stokehold this should not be the case; in fact, if sufficient air be supplied for the combustion of the furnaces there will be a constant and rapid current, and the atmosphere be actually purer than in other parts of the ship.

Engine-rooms and stokeholds should be supplied with fresh air by means of large ventilators carried from above deck and fitted with cowls turned to the wind. In other cases, windsails may be found of advantage.

In the Royal Navy, where everything is of necessity protected, and where forced draught is the exception, the question of the ventilation of the engine-rooms and stokeholds becomes a very difficult matter. In the majority of vessels of this kind fresh air is of necessity supplied by special apparatus, such as fan-blasts, &c. As may be readily imagined, firemen as a class are unhealthy, the effect of the stokehold on its occupants being detrimental to a high degree.

Both stokeholds and bunkers may be considered "workshops" where men are constantly feeding or cleaning fires and trimming coal. The fires are attended to from a platform 3 feet to 5 feet above the vessel's bottom, the most notable feature of which is its cramped and confined position and area. It can be understood that places so low down in the ship must in all cases prove difficult to ventilate. The conditions, however, vary in degree in almost all vessels, owing to the fact that few are built on exactly the same lines. As in the case of engine-rooms, but if anything in a more marked degree, abnormal heat is the most unfavourable condition under which the men labour. That this part of a ship exercises an unfavourable effect upon those called upon to work there is shown by the relative high incidence of suicide and mental derangement which occurs among firemen and stokers. Little improvement appears to have been made in stokeholds of the present day with regard to matters affecting the well-being of the men employed there, for the simple reason that, beyond engineers and those immediately concerned, few persons think of going near these remote and gloomy recesses in search of insanitary conditions. The modern developments of the turbine involve a notable reduction in size of engines and other machinery. A recent inspection of the stokeholds on one of this new type of vessel indicated marked improvements of conditions for the workers in this part of the ship.

Lavatories. In every ship proper provision should be made to enable men to keep themselves clean. There is no need for any elaborate arrangement, but there are few vessels where space cannot be spared for a reasonable lavatory and bathroom, while there is abundant evidence to show that seamen greatly appreciate and make good use of such accommodation. As a general principle, everything provided for the use of seamen should be of the simplest and strongest description possible. A comparatively small space will provide all that is required; water can be supplied by means of a tap, and in steamers there should be no difficulty in arranging for a hot

supply. A few basins can be readily fixed, with galvanised iron buckets provided for the washing of clothes. A galvanised iron bath of sufficient size and depth should be provided also. It is not necessary that this should be of sufficient length for a man to lie down, as thorough cleansing can be carried out in a squatting position provided the bath be deep enough for the purpose. The floor of such a lavatory should be covered with sheet lead, carried up the side for a short distance, and efficient means of drainage provided.

While this question of provision for the personal cleanliness of seamen and others in the mercantile marine is not specifically laid down either in Regulations of the Board of Trade or by schedule in the Merchant Shipping Act, it is otherwise as regards the Royal Navy. In that service there is a daily issue of fresh water every morning for personal cleanliness; moreover, by Article 531 of the Admiralty Instructions, the captain of every ship is directed to take care that all officers and men have ample opportunities to avail themselves of the special fittings provided in the ship for personal washing, and that bathrooms, when so fitted, are kept supplied with both hot and cold water, and also kept open for the use of those who desire it every evening after quarters. All commanding officers must see that proper times are appointed for washing the person, so that it may be a part of the daily routine. Special facilities are given in the navy to stokers and firemen for personal cleanliness, and in the larger ships special bathrooms with an unlimited supply of fresh water are at the disposal of these men. The consumption of fresh water in the navy for personal washing averages about one gallon daily per man.

Article 529 of the Admiralty Instructions directs that bedding be aired once a week when the weather will permit, each article being exposed separately to the air by being tied up in the rigging or upon girt lines. Twice in every year the blankets must be washed with soap in warm water; and once a year the bed tickings are to be washed, and the hair beaten and teased. Hammocks are usually washed every fourteen days; the allowance of fresh water for the washing of clothes and bedding in the Royal Navy is about two gallons weekly per man.

Closets and Removal of Excreta.—On ships, closets should be of the simplest description, as any complicated apparatus is certain to go wrong when used by the ordinary seaman. They should be provided on every vessel, and in the case of steamships can be always furnished with an efficient water-flush. The floor of the closet should be impermeable, the surface being finished with a good fall outwards. The structure should be of sufficient size for a man to stand upright in, and should be provided with ample light. The ventilation should be free and secured by louvred panels or simple holes in the door, with a scuttle out-board. The best form of apparatus is a short hopper made of galvanised iron attached to an iron soil-pipe, the apparatus being open to the air beneath. If the seat be made to lift up, the closet may be used as a urinal, thus obviating the necessity for what is always a source of trouble on ships. Passenger ships and the better class of vessels are usually provided with valve closets flushed with water from a cistern, and having a valve fitted to the lower end of the soil-pipe so as to prevent the entrance of sea-water. In these vessels the latrines for the crew are ordinary trough closets. In many of the small cargo-boats, the *pail* is the only form of convenience in use. In small yachts and some fishing-boats special kinds of closets are in use, especially where these conveniences must be placed below the water-line and where the ordinary discharge by gravity is impossible. In these closets the flush-water is

drawn directly from the sea by the user pulling the handle of a pump at his right side; the contents of the basin are discharged by a valve opened by a handle near his left hand. Any quantity of water may be used for flushing, and with ordinary care these closets answer their purpose well.

The soil-pipes of all ships' water-closets should discharge at a proper distance from the deck and out of sight. Where possible, closets should be in the after part of ships, so that the soil-pipe may shoot over or through the counter near the sternpost.

The closets for the crew should be near the men's quarters, but not so close as to cause any nuisance. Where a closet actually adjoins a forecastle, the bulkhead, if wooden, should be doubled with a layer of felt between the two thicknesses, and extra ventilation arranged for.

The proportion of privies or closets on passenger and emigrant ships required by the Board of Trade is at the rate of two for twenty of crew. Under the eleventh schedule of the Merchant Shipping Act, 1894, every passenger or emigrant ship must be provided with at least two privies, and with two additional privies on deck for every 100 passengers; and in ships carrying as many as fifty female passengers with at least two water-closets under the poop or elsewhere on the upper deck for the exclusive use of women and young children. The privies must be placed in equal numbers on each side of the ship, and need not in any case exceed twelve in number. All such privies and water-closets must be firmly constructed and maintained in a serviceable and cleanly condition throughout the voyage, and may not be taken down until the expiration of forty-eight hours after the arrival of the ship at the final port of discharge, unless all the steerage passengers quit the ship before the expiration of that time. In ships other than emigrant ships, when lying in dock, the usual regulation is that the closets should be cleaned and kept fastened, the crew, if remaining on board, going on shore for accommodation.

In the Royal Navy the usual form of closet for officers is that known as the "Duplex valve closet." The outlet of the pan is closed by two metal valves so arranged that while one is open the other is shut, and *vice versa*. The outlet of the soil-pipe is further protected by an automatically acting leather or metal valve. The escape of compressed or pent-up air in the soil-pipe is provided by means of a vent delivering outside the bulwarks. In torpedo-boats, where the closet is below the water-line, the special form of closet already described is provided. For seamen and the crews of warships ordinary trough closets or latrines are supplied at the rate of three for every hundred seamen and marines. These latrines are usually placed forward on one or both sides of the forecastle, and completely disconnected therefrom. Urinals are commonly put on the opposite side of the deck to the latrines. Closets for officers are placed either on the upper deck or on the fore part of the main deck.

Accommodation for Crew.—In merchant ships the crew are berthed either in forecastles or deck-houses. Forecastles are of two kinds, according to situation. The upper or top-gallant forecastle is placed upon the upper deck, right forward; it has side lights or scuttles, and is entered by a doorway. Lower forecastles are found only in small vessels. They are below deck, and are entered by a hatch, measuring usually $2\frac{1}{2}$ feet square and sometimes covered with a scuttle. Leading from the hatch into this forecastle is a ladder or flight of steep steps. This lower forecastle is a most unsatisfactory lodging, and one which it is scarcely possible to keep in a sanitary condition. The top-gallant forecastle is far preferable, but even there the common sanitary defects are bad ventilation, bad lighting,

indifferent heating, leaky decks, leaky side-posts, and condensation of moisture on the bare iron surfaces.

The ideal accommodation for seamen is undoubtedly the deck-house, now met with on the better class of British vessel, but most frequently seen on Danish and Norwegian merchantmen. These deck-houses are placed amidships, and have the sanitary advantages of light, air, accessibility, and possibilities for the greater convenience and comfort of their occupants. Even on small sailing-vessels it is found that the erection of deck-houses does not materially interfere with the working of the ship.

In some boats engaged in the cattle trade, the animals occupy the whole fore part of the vessel, while the crew are berthed below in the after part with the officers placed amidships in a deck-house.

The legitimate contents of crew spaces are hammocks or bunks, bedding, lockers, chests, a table, stove, and lamps. Unfortunately, many crew quarters too frequently contain other articles, which, to say the least, are improper. These articles embrace all the different materials and implements on board which it is possible to stow away, notably sails, cordage, spare blocks, cans, buckets, brushes, paint, tar, oil, paraffin, wet clothes, boots, and even provisions. These various articles not only pollute the air, but materially occupy space, and that illegally. The principal defects of sailors' quarters may be summed up as insufficient height, light, ventilation, and means of heating; to these may be added effluvia from cargo or bilge-water, improper storage, and overcrowding.

The following Table shows approximately the cubic and floor space per head found in the crew spaces of a variety of vessels registered under the Merchant Shipping Acts:—*

Type of Vessel.	Tonnage.	Situation of Crew Spaces.	E or L.†	Cubic Space per Head.	Floor Space.	
					Per Head.	Clear.
Sailing-barges on River Thames	34 to 50	Cabin aft	E	302	40	20
Ketch rig	50 to 75	Lower forecastle	E	290	38	24
Schooner rig	75 to 200	Lower forecastle	E	239	34	21
Ship rig	1,200 to 2,500	House on deck	E	143	21	—
Steam trawlers	200 to 250	Top-gallant forecastle	E	178	25	17
Steam coasting colliers	1,000 to 2,000	Top-gallant forecastle	E	170	20	15
Steam coasting cargo	150 to 750	Lower forecastle	E	388	50	36
Steam passenger cross-channel	500 to 1,300	Lower forecastle	E	118	16	—
Steam passenger (coasting)	600 to 1,300	Lower forecastle	E	115	15	—
Ordinary tramp steamers	1,000 to 4,500	Top-gallant forecastle	E	122	12 to 15	—
Steam liners	3,000 to 8,000	Forecastle and poop	L	100	14	—
Steam liners	3,000 to 8,000	Forecastle and poop	L	131	14	—
Atlantic liners	6,000 to 20,000	Forecastle	E	132	17	—
Other liners	5,000 to 10,000	Forecastle and poop	E	115	15	—

† E = Europeans. L = Lascars.

The Merchant Shipping Act, 1894, section 210, requires that every seaman shall have 72 cubic feet of air space and 12 square feet of floor area, and that such space shall be entirely free from stores, &c. This, the legal minimum limit, is certainly too small. Fortunately, in the larger vessels there is a tendency rather to underman than to overcrowd; hence it is not

* An interesting summary of "Sanitation in the Merchant Service," by W. G. Romeril, which appeared in the *Sanitary Record*, September 20, 1906, and following issues should be consulted. This Table appeared December 27, 1906.

unusual to find fewer men occupying a given crew space than could be allotted to it. On the other hand, there are a certain number of vessels on which the minimum only is provided, and the opinion prevails that this allowance should be increased to not less than 100 cubic feet per head. If the height of the forecastle were 6 feet, this would allow 16 square feet per man, or a fairly reasonable allowance.

It is noticeable that the Act of 1894 does not specify that a crew space shall be of any particular height, but merely provides that every such place shall be such as to make the space "available for the proper accommodation of the men who are to occupy it"; it also provides for a minimum amount of cubic capacity, as well as a minimum amount of floor space per man.

In iron ships moisture frequently condenses from the air of the crew's quarters on to the metal plates and beams overhead, rendering the apartment damp generally, and also dropping into the bunks and wetting the seamen's bedding. This evil can be remedied by sheathing the metal with wood, or covering it with thick varnish and dusting thereon finely granulated cork. Where wood sheathing or sweat-boards are used, this lining often serves as a resting-place for filth and vermin. The surveyors of the Board of Trade are instructed not to sanction wood lining unless fitted quite close to deck and sides.

Seamen's bunks should be arranged so as to leave a clear space between them and the ship's side. This space should be wide enough for a man to pass round for cleaning and painting purposes. In no case should a crew space be certified for a greater number of seamen than there are bunks fitted for. The bunks themselves should be made of iron covered with a non-conducting composition. They should be not less than 6 feet long by 2 feet wide, and arranged in two tiers only; the distance between the tiers and between the upper tier and the deck should not be less than 2 feet 6 inches. The bottom of the lower bunk should be at least 12 inches above the floor level, so as to permit of thorough cleansing underneath. Hammocks are preferable to bunks as sleeping accommodation for seamen, on account of their being more cleanly and occupying less space.

In all forecastles and crew spaces the decks or floors must be of wood, not less than 2½ inches thick, properly laid and caulked. Planks laid on quartering over an iron deck, or loose boards on an iron deck, are inadmissible. The floor or deck should slope to a well-constructed water-way, which should be efficiently drained by trapped scuppers so placed that they can be readily seen and cleaned.

In the Royal Navy the crews of battleships and first-class cruisers are commonly berthed between decks; but in some of the smaller cruisers there is accommodation in the top-gallant forecastle. As in the merchant vessels these forecastles are apt to be damp and unhealthy, owing to water gaining access through the hawse pipes when the ship is under way. There appears to be no exact scale of berthing accommodation for seamen and marines laid down by the Admiralty. The number berthed in any given space is mainly determined by the so-called hammock space; the usual interval between the hammock hooks as seen projecting downwards from the beams or girders being 18 inches. The cubic space actually available in the crew spaces varies in different classes of ship and often in different parts of the same ship; it may be roughly stated to vary from 100 to 200 cubic feet per man. In the naval transports or troopships, the ship's company are berthed separately in the forecastle, while the troops are placed in the main deck and in the fore part of the lower deck. In these ships the actual cubic

space available for both sailors and soldiers is little in excess of 80 cubic feet per man.

Accommodation for Passengers.—As regards accommodation for passengers and emigrants there are special provisions in the Board of Trade's Regulations and in the tenth and eleventh schedules of the Merchant Shipping Act, 1894, which direct "that the height between decks must not be less than 6 feet, that there must not be more than two tiers of berths on any one deck, and that the height between the tiers and between the upper tier and the deck overhead must not be less than 2½ feet. In respect of floor area, it is laid down that on the upper passenger deck there must be at least 15 square feet, and on the lower passenger deck 18 square feet for each adult; but if the height between decks on the lower passenger deck be less than 7 feet, and if the apertures (exclusive of side scuttles) through which light and air are admitted together are less in size than in the proportion of 3 square feet to every 100 superficial feet of that deck, then the floor area of each adult must be at least 25 square feet."

The Board of Trade's Instructions as to Survey, 1895, enact that the number of passengers to be carried in the after-cabins, saloons, or fore-cabins must be determined by the number of berths or sofas, properly constructed for sleeping-berths, and so much of the floor area of the saloons or principal cabins as is not covered by tables or permanent fittings may be measured at the rate of 9 square feet for each passenger. The floor of state rooms is not to be counted for passengers, but the berths may be counted, provided there are 72 cubic feet of space in the state room for each passenger.

The aggregate number of passengers other than saloon or first-class passengers, as certified on the passenger certificate of any vessel or ship, is limited to six times the number for which there is a clear sheltered space for the voyage; such sheltered space may be either space in a house on deck, or in a cabin below deck, or under a waterproof turtle-back open only at the after end, or in two or more of such spaces.

Clear space on the spar- or weather-deck must be left for the use and exercise of passengers, at the rate of at least 10 superficial feet for each adult. No greater number of passengers may be carried than in the proportion of fifteen for every 100 tons of a ship's registered tonnage.

Accommodation for Sick Persons.—In respect of hospital accommodation on ordinary merchant ships there appears to be no definite regulation, although it is clear that on every vessel of any size some special arrangement should be made for the berthing of sick members of the crew. The position of such accommodation will necessarily vary according to circumstances, but all that is essential is a well-ventilated isolated structure, fitted with an iron cot, washstand and seat. This much at least should be available in case of accident or illness where a patient requires to be kept quiet, or in the event of infectious disease. In this latter circumstance, provision of such means of isolation are obvious and cannot be too strongly insisted upon.

In vessels carrying passengers or emigrants, the Merchant Shipping Act and Regulations of the Board of Trade demand the provision of hospital accommodation in the proportion of not less than 18 square feet of floor area for every fifty passengers. The lighting and ventilation must be such "as the circumstances of the case may, in the judgment of the emigration officer at the port of clearance, require."

In the Royal Navy the hospital accommodation or *sick bay* is usually constructed in definite relation to the number of the crew on any given

vessel. The usual proportion in battleships is a sleeping accommodation for 3 per cent. of the total ship's complement, the floor area allowed being from 20 to 30 square feet per man. The location of the sick bay varies in different classes of ship. In the more modern large battleships it occupies the midship part of the main deck, where it is lighted and ventilated from above, and also by means of louvres and gratings in the bulkheads. In some few other large ships it is on the upper deck inside the superstructure, where it receives natural ventilation, and is lighted from above. In the smaller ships the sick bay is situated on the fore part of the main or lower deck. In these cases, natural ventilation is the exception, and provision is made for special means of lighting and supply of fresh air.

Prisoners in the Royal Navy receive special accommodation on board battleships and cruisers. This accommodation consists of special cells, usually placed on the main or lower decks. In size they average 200 cubic feet per man; if not ventilated by natural means, they are always specially connected with the system of artificial ventilation provided for the ship.

Ventilation on Shipboard.—This is one of the most important points to be considered, and often one of the most difficult to satisfactorily arrange. The ventilation of ships has been aptly compared to that of an uncorked bottle, and the larger the vessel the more complex does the question become.

Although the *air* of ships is sweet and fresh above deck, it is notoriously foul below. The chief causes of this are:—(1) excessive humidity, arising not only from respiration, but from washing of decks, and the wetting of the various parts by sea-water gaining access in rough weather; (2) excess of carbon dioxide associated with organic effluvia, attributable to respiratory vitiation and the products of combustion from oil lamps or candles; (3) sulphides of ammonium and hydrogen emanating from the bilges, and the product of chemical interaction between sea-water, wood or metal work, oil, cotton waste from engines, soap, paint, decomposing organic matter, dead rats, coal dust, and cargo material of various kinds; (4) effluvia from cargoes, more particularly from cattle, sugar, grain, lime, guano, compressed fuel, bones, fish, onions, tar, and petroleum; (5) gases from coal bunkers, the products of heat and moisture.

In respect of the evil effects of cargoes on the air of ships the following legislative enactments are of importance. The Board of Trade Instructions as to Survey, 1895, provide, "that every place occupied by seamen shall as far as practicable be shut off and protected from effluvium which may be caused by cargo or bilge-water; the surveyor must, therefore, see that the bulkheads, sides, and decks of the crew spaces are so fitted, laid, and caulked, and are of such thickness that this provision is complied with, &c. The bulkheads, if made of wood, should be constructed of well-seasoned material, and, besides being tongued and grooved, should be doubled with felt between, or battened over the seams with felt under the battens."

In passenger or emigrant ships, under the Merchant Shipping Act, 1894, schedule 13, it is provided that "animals shall not be carried on any deck below that on which passengers are berthed, nor in any compartment in which passengers are berthed, nor in any adjoining compartment, except in a ship built of iron, and of which the compartments are divided off by watertight bulkheads extending to the upper deck."

Passenger ships of less than 500 tons register may not carry more than two head of cattle, nor, in larger vessels, more than one additional head for every additional 200 tons, nor more in all than ten head of large cattle. The expression "large cattle" includes both sexes of horned cattle, deer,

horses, and asses; and four sheep of either sex, or four female goats, are deemed equivalent to, and, subject to the same conditions, may be carried in lieu of one head of large cattle. Not more than six dogs, and no pigs or male goats, may be conveyed as cargo in any passenger or emigrant ship.

Speaking generally, the ventilation of ordinary merchant or trading vessels is not well attended to. The means and appliances are not always there, and, when provided, their use is often neglected. It is otherwise in the mail or passenger ships and in the ships of the Royal Navy, where the efficiency of the crews is fully appreciated; but even in these vessels it is evident from the mere number and variety of appliances in use that the ventilation is not perfect.

As regards methods of ventilation on ships, their principles and application do not differ materially from those of ventilation on shore, as already enunciated in Chapter IV. of this book. Where possible, natural ventilation is aimed at, but in the larger vessels and in men-of-war, owing to peculiarities of structure, natural methods are impossible; in them ventilation can only be secured by artificial means, and even then often but imperfectly. The special appliances used for effecting natural ventilation in ships are hatchways and skylights, ports and scuttles, windsails and trysails, fixed tubular ventilators, hollow iron masts, and the funnel casing. For artificial ventilation the chief appliances employed are the funnel and funnel casing, rotary fans, steam ejectors, compressed air, Perkin's ventilator, and punkahs.

In lower forecastles on small vessels the hatchway is practically the only inlet and outlet for air, and in stormy weather is usually closed. Sometimes this hatch has a scuttle with side openings, but quite insufficient for the object desired. A few lower forecastles have a hole of 6 inches diameter through the roof, fitted with a cowl or mushroom ventilator, but this is often closed.

The top-gallant forecastles of the larger sailing-vessels and steamers have side ports or scuttles opening to the outer air in addition to other means of ventilation. In cattle steamers or other cargo boats, where a large amount of fresh air is needed, the ventilation of the decks and holds is commonly effected by ordinary circular cowled tubes and by large flat-sided shafts, the tops of which are provided with hinged flaps to direct the air downwards. Holds are almost invariably ventilated by windsails, trysails, or fixed tubular ventilators surmounted by a cowl. The height of these is regulated by the height of the structure in front of them, but in no case should there be less than 6 feet from deck to bottom of cowl or mouth.

The windsail or trysail is practically a canvas cowl, consisting of a tube or shaft, the upper end of which is fitted with wings or valves to direct the wind down the tube. It is most commonly met with in the naval service. The principle upon which it acts is like that of ordinary tubular fixed ventilators having an adjustable cowl, or the propulsion of fresh air into the parts to be ventilated by means of the ship's motion. All these contrivances are inoperative unless the inlet be directed to the wind. In calm weather they are more or less useless unless the vessel be moving swiftly.

In modern ships the employment of hollow iron masts constitutes an important means of ventilating holds and spaces between decks; in a similar way the bitts are often made hollow in iron ships and can be made to act as ventilators. The funnel casings, also, of steamers can be perforated with gratings or louvres, and, independently of its artificial action by virtue of an up-draught produced in it by heat radiated from boilers, funnel and steam-pipes, is naturally and directly available as an outlet for the removal of vitiated air from the decks.

As to whether any given crew space is properly ventilated on a merchant vessel, the decision rests with the surveyor of the Board of Trade. His "Instructions" on this point are as follows :—"The simplest method is to have an iron pipe with a revolving cowl, which in lower forecastles must be as high as the bulwarks, fitted at each end or side of the crew space, so that while impure air escapes at one, pure and fresh air will enter at the other, and a constant circulation be kept up. Where such means for ventilation are adopted, one of the ventilators should pass through the deck to at least the lower side of the beams." Mushroom ventilators should be discouraged, as the screws are liable to rust and to become jammed, while the opening is usually much less than the sectional area of the tube. The Board of Trade do not permit these ventilators unless they are at least 30 inches high for top-gallant forecastles and as high as the bulwarks for lower forecastles. Scuttles, companions, and doors are not to be considered as efficient means of ventilating crew spaces. There must always be two ventilators. Among other provisions for top-gallant forecastles is one for openings in the top and bottom of the bulkheads, covered with perforated zinc, and fitted with doors for closure.

Under the Merchant Shipping Act, 1894, it is enacted that "no passenger ship shall clear out or proceed to sea without such provision for affording light and air to the passenger decks as the circumstances of the case may, in the judgment of the emigration officer at the port of clearance, require ; nor, if there are as many as one hundred passengers on board, without having an adequate and proper ventilating apparatus, to be approved by such officer, and fitted to his satisfaction ; the passengers shall, moreover, have the free and unimpeded use of such hatchway, situated over the space appropriated to their use, &c.

The various means of securing ventilation on ships, as yet mentioned, include only those more or less available through the ordinary openings of the different parts of the vessel. These, though useful in their way and under appropriate circumstances, are only of limited value. Some are only available during fine weather, while others are only of use in certain ships or parts of ships. It is, therefore, necessary to secure ventilation by some other means, such as can be used at all times, in all weathers or climates, and on all parts of vessels, independently of whether they are cargo, passenger or war ships. All artificial systems of ventilation, whether on shore or on ships, act either by (*a*) extraction, (*b*) propulsion, or (*c*) by a combination of both.

Experience shows that, on ships, the most satisfactory system of artificial ventilation is one by propulsion. The interior of a ship, especially a large ship, is so complicated that ventilation by extraction or exhaust, unless maintained for a long period, will produce no appreciable improvement in the state of the air in the more remote parts. Under similar conditions, if the system of air-trunks, shaft and delivery tubes be well planned, artificial ventilation by propulsion is readily efficient throughout the largest vessels. The comparative value of artificial ventilation methods has been discussed already on page 188 *et seq.*, and the general arguments there expressed are fully applicable to the conditions met with on board ships. Just as in mines, tunnels, and buildings on shore, so in ships the resistance to the movement of the air due to friction from the air-trunks, abrupt turns, angles, bends, expansions and contractions of ducts, and from eddies is enormous, so much so that a large part of the power employed to produce air-currents is needed to overcome this resistance ; and, moreover, ventilating engines on board ship as elsewhere are usually constructed so as to provide a large reserve of power for overcoming such resistances.

In respect of the general conformation of air-trunks and ducts in ships, although the circular or cyclindrical form is more economical as regards friction, owing to exigencies of ship construction, it is the practice generally to adopt rectangular ducts in all large vessels. These various air-trunks are usually provided with valves, in order to prevent the passage of water through watertight bulkheads by means of these air-channels, in case of accident. In men-of-war these valves are further necessitated in order to enable communication by the ventilating tubes between the magazines and the rest of the ship to be shut off in case of fire. The actual air-valves are either automatic or hand-worked. In some cases the occlusion of the lumen of the air-trunk is secured by the rising of a float on the incoming water; in others a hollow metal float releases a catch which permits a weighted sluice-valve to close the air-tube. In men-of-war all air-tubes passing through watertight bulkheads and protective decks are automatic; those in the magazine air-tubes are hand-sluices.

The following is a summary of the many forms of apparatus for artificial ventilation that have been or are now used in ships :—

(1) Pipes from the hold, &c., opening beneath or over fires. The draught induced by the heat removes the foul air from the lower parts of the ship to the fire, where it is consumed.

(2) Placing special exhaust or foul-air pipes inside the funnel casing of steamships.

(3) Steam or gas jets discharging into exhaust pipes. Edmund's steam jet is in use in the navy.

(4) Air-pumps fitted to special outlet tubes.

(5) Cowls of various kinds fixed to exhaust pipes. In Boyle's system, by this method fresh air is introduced by special downcast ventilators.

(6) Jets of compressed air discharging into a main air-trunk. This is D. C. Green's system in use on some merchant ships. The air is under a pressure of from 3 to 4 lb. per square inch, and the discharge of a cubic foot of this compressed air is said to induce the discharge of 25 cubic feet of ordinary air. This system can be used for either propulsion or extraction.

(7) *Perkin's automatic ventilator* is an exhaust arrangement which in various forms has been tried with indifferent success in the navy, and depends for its action upon the rolling or pitching motions of the ship. It consists of two cylindrical tanks placed one on each side of the deck, and connected below by a horizontal tube. From the upper part of each vessel pass two tubes; one leads upwards to the outer air, the other downwards to the space to be ventilated. Each of these tubes is fitted with valves. Each cylinder is filled half-full with water. As the ship rolls, water gravitates from one tank to the other, and by so doing sucks foul air into one vessel and expels it from the other. It is practically an automatic air-pump, but only capable of action when the ship is rolling or pitching. It is placed diagonally in the ship, but, owing to the small volume of air operated upon, does not give results commensurate with the space which the apparatus occupies. The same principle has been adopted in the ventilating pumps of Thiers of New Orleans and of Roddy of New York; neither of these arrangements has been altogether satisfactory.

(8) Rotary fans of various kinds. The general principle and power of these appliances have already been considered. Their use is very general in the Royal Navy, especially in the form of centrifugal fans varying from 3 to 6 feet in diameter. Blackman's fans, which are not centrifugal, are not much used in His Majesty's ships, except for moving air in comparatively small spaces, such as cabins.

Heating and Lighting.—Apart from considerations of climate, the temperature or warmth of a ship depends upon the material of which she is constructed, whether she is propelled by steam or not, and upon the condition and nature of her cargo. Sailing-ships are as a rule colder than steamers; this is mainly due to the large amount of coal used on these latter vessels. This extra heat is naturally greatest near the furnaces, and not unfrequently is conveyed to different parts of the vessel by steam-pipes, from which, if not suitably covered by some non-conducting material, an enormous waste of heat takes place.

Allusion has previously been made to the excessive temperatures which often prevail in engine-rooms and stokeholds. In many cases this condition arises from insufficient ventilation, and, unless suitable provision for the admission of fresh air to the stokeholds is made, the fires will not burn properly. If adequately ventilated, in tropical climates, the stokeholds of large vessels are often the coolest part of a ship. The holds of ships, especially sailing-ships, are frequently warmer than other parts. This is partly due to its depths from the external air, but more commonly depends on heating of the cargo. Certain cargoes, such as coal, grain, lime, sugar, and many others, are apt to undergo various chemical changes attended with the evolution of much heat; this is particularly the case if the cargoes be stowed when damp, or if the hold in which they are placed be insufficiently ventilated. In steamships, a common source of increased temperature in the holds is the blowing out of hot water from the boilers into the bilges.

Iron ships are peculiarly liable to extremes of temperature, owing to the readiness with which the metal conducts heat.

As regarding the efficient heating of crew spaces on ships, there appears to be no official ruling. The various parts of ships are usually warmed artificially by fireplaces, stoves, or by steam-pipes or radiators. In the forecastles of merchant vessels there is usually a "bogey" or small square stove, constructed of thin cast-iron with a movable cover. It has many disadvantages; it requires constant attention, when heated allows the products of combustion to pass freely through its substance, readily cracks, is dangerous as a constant source of accident, is dirty, and from its shape clumsy and inconvenient. One of the rarest sights on board ships is a bogey stove in perfect condition. Much improvement might be made in crew spaces were a more rational stove made compulsory in these parts of ships. Probably the best and most economical stove would be a well-constructed, circular, wrought-iron, slow-combustion one, lined with fire-clay. The flue should be of iron, connected to the stove by means of a curved pipe. The funnel should pass through the deck by a properly constructed flange and terminate in a cowl. When not in regular use, the stove might be disconnected and the cowl remain as a ventilator. Or the funnel of the stove might be made to pass up through the centre of an ordinary ventilator, allowing the smoke to escape at a higher level; the general effect of this arrangement would be to heat the air in the ventilator and so cause a considerably increased discharge by the outlet shaft.

While the *lighting* of the cabins of ships' officers and saloon passengers may be said to be fairly good, the reverse is too often the case in respect of emigrants and seamen. These deficiencies are commonly more apparent to occupants during the day than at night, as during this latter period illumination is effected by means of oil, candles, or electricity.

The following are the official instructions to surveyors of the Board of Trade upon this important point. "Every space appropriated to crew space should be properly lighted. To ensure that such will be the case

under the ordinary conditions of a vessel's employment, it will generally be necessary to have so much provision for light when the ship is new and the paint clean, that if one-third of it be closed it will be possible to read the print of an ordinary newspaper in any part of the space."

Although the necessity at times of supplying light to forecastles by means of glass prisms or bull's-eyes in the deck is recognised, the Board of Trade discourage their use, except in cases where it is impracticable to obtain the requisite amount of light by other means, or in small vessels where side scuttles would be too near the water. The maximum diameter for side scuttles is fixed at 10 inches, as a larger size may weaken the structural strength of the side plating of a vessel.

Cleansing and Disinfection of Ships.—The unclean condition of ships, more particularly small ships, cattle-boats and fishing-vessels, is very common, not only in parts which are out of sight, but on their decks, forecastles, cabins, and holds. In the Royal Navy and on the better vessels of the mercantile marine, daily inspections are made by the ship's officers of the various parts in order to ensure their being kept thoroughly clean, and this routine needs to be strictly carried out. Merchant ships, as a rule, are not kept so clean as warships, which, in the Royal Navy, by Article 529 of the King's Regulations (1904), it is the duty of the captain to strictly supervise and also to cause the holds to be whitewashed every six months or oftener if necessary.

In the Royal Navy the decks are cleaned by holystoning (wet or dry) and in the berthing parts by scraping and scrubbing with hot water, wetting only small portions at a time and drying thoroughly. The two former methods are open to objection in the inhabited parts of the ship, one from filling the air with dust, the other from loading it with vapour.

The commonest fault committed in cleansing ships is to employ water too frequently and in unnecessarily large quantities. Thorough scrubbing and cleansing can be effectively carried out without the use of large quantities of water, which very often, by accumulation charged with organic matter in out-of-the-way corners, are productive of more trouble than the original dirt. There is much reason to believe that the unhealthiness of many ships in tropical parts is due to this cause; the more ships wash their decks in these places, the more sickly they are; the organic matter in suspense in the water is left upon the decks as they dry, with disastrous results. Great care should be taken to see that all superfluous water is removed, and that the forecastle is dried as quickly as possible; in wet or damp weather dry scrubbing should always be resorted to. It cannot be too clearly understood that "a damp ship is an unhealthy ship." Flushing with water or wet scrubbing should not be carried on when there is less than three degrees difference between the readings of the dry and wet bulb thermometers placed under a screen in the open air. It should also be a rule that, whenever the weather will permit, all bedding should be removed from the forecastle or crew berth-spaces and exposed to the sun and wind for a certain time every day.

As regards the details necessary for the proper drainage and cleansing of merchant ships, their provision and supervision rests with the surveyor of the Board of Trade. His instructions upon this matter practically amount to this:—That he will see that there are holes, sufficient in number and size, through the cant or coaming of upper forecastles and deck-houses, to admit of a ready escape of water, and that there are plugs, with lanyards or chains attached, fitted to each hole. Where such drainage passes through a privy or other compartment, it is necessary to have a pipe for the drainage

to pass through such privy or compartment, with the pipe made perfectly tight through the cant or coaming.

The most difficult parts of a ship to keep sweet or fairly clean are the bilges; that this is the case is readily understood from the nature of the material and refuse which they constantly receive. Bilges should not be flushed out with sea-water, neither should reliance be placed upon the use of deodorants or antiseptics; the only efficient means of keeping the bilges sweet is to pump them dry periodically and completely remove overboard the bilge-water itself. After being pumped dry, they may be flushed with fresh sea-water or with water mixed with a disinfectant or antiseptic.

The question of the disinfection of ships need not be reconsidered in this place, as it has already been discussed on page 763.

Water-supply of Ships.—Except in small sailing-vessels, the question of supply is no longer a difficult one, inasmuch as condensation and subsequent aeration can always be resorted to; however, difficulties often exist in regard to source and storage.

In ports, ships are usually furnished with water by "water-boats" fitted with tanks, from which the supply is pumped to the vessel requiring it; or direct from companies' mains. The former method has grave objections, owing often to the water-boats being dirty or having leaking decks, also owing to the difficulty, in cases of enteric fever, &c., of ascertaining the source from which the water-boat derived its supply. Where water-boats are the means of supply, a responsible ship's officer (the surgeon if one is carried) should always inspect the barge and examine the water before allowing it to be delivered on board, and should further insist upon the hose being washed by the first pumpings before the end is put into the ship's tank. Under no circumstances should water be taken from a wooden water-barge. In the Royal Navy the rule is that no water is to be taken or used on board ship until it has been examined and passed by the surgeon.

In foreign ports the water is often of doubtful and in some cases of absolutely harmful quality. In many such ports in place of methods of supply, as above detailed, recourse has to be made to fetching the water from shore, either in casks and barrels, or by clearing the ship's boats of all removable gear and then filling them with water; finally towing them back to the vessel, where the water is pumped on board. Sometimes this latter method is improved upon by fitting each boat with a collapsible canvas bag. These methods are obviously objectionable, since the water may be, and often is, fouled by leakage of sea-water through the boat's sides, or by washing in over the gunwale.

As an alternative to the foregoing sources of water-supply, all large steamships and vessels of the Royal Navy rely upon the distillation of water from sea-water. There are a large number of distilling apparatus which have been approved by the Board of Trade; those of the first class will distil as much as 800 gallons in ten hours. The Board of Trade's regulations as to the survey of steamships carrying passengers state that the distilling apparatus should, with certain exceptions, be taken to pieces every voyage and tested. "The water should be cold, pure, and fit to drink immediately after it is drawn off from the filter. No distilling apparatus should be passed unless fitted with a suitable sized filter, charged with animal charcoal."

The storage of water on ships is a difficult and unsatisfactory matter. In small vessels, casks are still in common use; they should be abolished altogether except in cases of emergency. The alternate wetting and drying rapidly sets up decomposition of the wood, and this being favoured by want

of ventilation pollutes the water, rendering it unfit for dietetic purposes. If wooden casks are used, they should be properly charred inside, and not capable of containing more than 300 gallons; the staves should not be made of fir, pine, or soft wood. In large ships water is stored in galvanised iron tanks, holding often 600 gallons or more each. These, painted outside and cement washed within, form the most economical, and at the same time fairly sanitary receptacles. They need to be furnished with large manholes for the purpose of cleansing, which should be carried out as a matter of routine after each voyage. If possible, the manhole should be placed in such a position that natural light finds its way into every part of the tank when the cover is removed. Unfortunately, too often these water-tanks are placed in most awkward and inaccessible parts of the ship, with the result that their supervision and cleansing are frequently neglected.

On ordinary merchant ships the supply carried must be equal to a daily allowance of 3 quarts per statute adult, exclusive of the quantity necessary for cooking, which latter must be shipped at the rate of at least 10 gallons for every day of the prescribed length of the voyage for every 100 statute adults on board (section 295, Merchant Shipping Act, 1894, read in conjunction with the twelfth schedule of same Act). Passenger ships provided with proper distilling apparatus, however, are required to store only half the above amount of water.

In the Royal Navy, the *King's Regulations and Admiralty Instructions* (1904), Appendix XXI., state that for troops or third-class passengers water "is to be issued on the most liberal scale possible; and the minimum daily allowance of water is to be, for each individual embarked, 6 pints when out of the tropics, and 1 gallon when within the tropics, which quantities are to suffice for all purposes." For the crews and complement of warships there is no definite enactment in the Admiralty Instructions as to the amount of water to be issued daily. General precautions are taken to prevent waste, but practically the sailor receives an unlimited supply. The daily average consumption of water on ships of the Royal Navy is 4 gallons per man, and of this some 2½ gallons are used for personal and clothes washing.

For the purification of water in the mercantile marine, various filters charged with animal charcoal are in use. For the same purpose, in the navy, Morris's filter containing manganous carbon, Crease's filter charged with carbalite, and a special form of filter charged also with carbalite, and usually fitted in the bottom of a water-tank, appear to be chiefly employed. The general conditions and principles of water purification on board ship do not differ from those already explained under the chapter on WATER; it is probably merely a question of time and the dissemination of a better knowledge concerning the fallacies and dangers attaching to the use of imperfect filters, for the use of those of the Pasteur-Chamberland type to be officially required not only on vessels of the Royal Navy but in the greater number of those belonging to the mercantile marine. Equally promising results might be obtained on shipboard by some chemical treatment of water as discussed in the chapters on Water and on Military Hygiene. The practical application of methods of this nature appears still to be in its infancy. Prejudice and ignorance appear to be the main stumbling-blocks to any departure from precedent and routine.

Food on Shipboard.—The true economy and importance of providing the sailor with good and adequate food is sufficiently self-evident to need no special arguments in this place. Yet notwithstanding a practically unanimous opinion on this point, it is astonishing how little attention is really given to the feeding of seamen by those who employ them.

For the merchant service there is no official dietary scale; what food a seaman shall receive in any given ship or for any given voyage is entirely a matter of contract between the master and the man, and the Board of Trade merely see that the scale is inserted in the articles of agreement. The Merchant Shipping Act simply requires that *a* diet scale shall form part of the agreement, but in no way (except so far as lime-juice and sugar are concerned) indicates what such diet scale should be. The following tabular statement practically represents the diet scale usually signed for by the crew in the majority of British ships:—

	Bread.	Flour.	Beef.	Pork.	Peas.	Sugar.	Coffee.	Tea.	Water.
	lb.	lb.	lb.	lb.	pts.	oz.	oz.	oz.	qts.
Sunday . . .	1	$\frac{1}{2}$	$1\frac{1}{2}$	—	—	2	$\frac{1}{2}$	$\frac{1}{8}$	3
Monday . . .	1	—	—	$1\frac{1}{4}$	$\frac{1}{3}$	2	$\frac{1}{2}$	$\frac{1}{8}$	3
Tuesday . . .	1	$\frac{1}{2}$	$1\frac{1}{2}$	—	—	2	$\frac{1}{2}$	$\frac{1}{8}$	3
Wednesday . .	1	—	—	$1\frac{1}{4}$	$\frac{1}{3}$	2	$\frac{1}{2}$	$\frac{1}{8}$	3
Thursday . . .	1	$\frac{1}{2}$	$1\frac{1}{2}$	—	—	2	$\frac{1}{2}$	$\frac{1}{8}$	3
Friday . . .	1	—	—	$1\frac{1}{4}$	$\frac{1}{3}$	2	$\frac{1}{2}$	$\frac{1}{8}$	3
Saturday . . .	1	—	$1\frac{1}{2}$	—	—	2	$\frac{1}{2}$	$\frac{1}{8}$	3

This dietary has a mean daily nutritive value of:—Proteins, 148 grammes; fats, 25·5 grammes; carbo-hydrates, 375 grammes; and salts, 80 grammes. On some ships extras are allowed; thus, very often a fresh mess, composed chiefly of soup-bouilli, is given on Sundays in addition; occasionally preserved meat is substituted once a week for salt meat; sometimes a certain quantity of butter is served out instead of a portion of meat, while a few owners issue marmalade and pickles. In some coasting vessels, in which the labour is hard, the dietary is practically unlimited.

In addition to the foregoing or other articles of ordinary diet, the Merchant Shipping Act, 1894, section 200, demands the issue of lime- or lemon-juice with sugar (the sugar to be in addition to any sugar acquired by agreement with the crew). This lime- or lemon-juice must be served out daily at the rate of an ounce per day to each member of the crew, so soon as they have been at sea ten days, and during the remainder of the voyage, except during such time as they are in harbour and are there supplied with fresh provisions. Before being served out, the lime- or lemon-juice must be mixed with a due proportion of water; further, no lime- or lemon-juice may be taken on board ship for issue to the crew unless it has been obtained from a bonded warehouse for and to be shipped as stores; moreover, it may not be so obtained or delivered unless it contain 15 per cent. of proper and palatable proof spirit, to be approved by the Board of Trade inspector, or by the proper Officer of Customs.

Whilst fully admitting the grave difficulties in the way of securing satisfactory food on board ships, there appears much necessity for having the rations of coasting as well as ocean-going ships fixed by law. The chief defects apparent in the customary diet are:—(1) monotony, (2) excess of salt meat, (3) deficiency of vegetable food, and (4) improper proportion of the different ingredients, more particularly an excess of proteids with a deficiency of fats and carbo-hydrates.

The regulations of the Board of Trade for the inspection of the provisions and water of ships are sufficiently comprehensive. They relate to notice being given to the inspector for the inspection of stores, and for supplying him with a list of all stores; they also provide for the inspection of all surplus stores left over after a previous voyage, and for turning out the

contents of all casks of wet provisions among such surplus stores. The requisite condition of beef, pork, preserved meats and vegetables, vegetables in tins, flour and biscuits is defined. Briefly stated, " animal food is to be sweet and properly packed and pickled in pickle of full strength ; vegetables are to be sound and fresh, properly preserved, and in strong and suitable tins. Flour is to be of fine grade, milled from fully matured, good sound wheat, containing a proper proportion of nutritious matter, and packed in suitable casks or tanks. Biscuits are to be thoroughly baked and dried and made of fully matured wheat-flour. When stored in tanks, these are to be thoroughly cleansed, lined with fresh lime and dried before being refilled. The water left in the ship's tanks from a former voyage must all be completely emptied, and the tanks thoroughly cleansed and refilled with good fresh water."

A noticeable defect on board many merchant vessels is the want of proper places in which to store provisions ; the result being that they are often exposed to unwholesome exhalations. It is not at all unusual to find on some vessels that the bread store opens into the crew's quarters, or that portions of the crew's food are kept in the forecastle. Such arrangements are obviously in violation of all sanitary teaching, and need not only official condemnation but legislative prohibition.

	Weekly Allowance per Statute Adult.			
	Scale A. For Voyages not Exceeding 84 Days in Sailing-ships or 50 Days in Steamers.		Scale B. For Voyages Exceeding 84 Days in Sailing-ships or 50 Days in Steamers.	
	lb.	oz.	lb.	oz.
Bread or biscuit	3	8	3	8
Wheaten flour	1	0	2	0
Oatmeal	1	8	1	0
Rice	1	8	0	8
Peas	1	8	1	8
Potatoes	2	0	2	0
Beef	1	4	1	4
Pork	1	0	1	0
Tea	0	2	0	2
Sugar	1	0	1	0
Mustard	0	$0\frac{1}{2}$	0	$0\frac{1}{2}$
Black or white pepper, ground	0	$0\frac{1}{4}$	0	$0\frac{1}{4}$
Vinegar	One gill.		One gill.	
Lime-juice	—		0	6
Preserved meat	—		1	0
Suet	—		0	6
Raisins	—		0	8
Butter	—		0	4
Salt	0	2	0	2

Scale of Substitutes.

1 lb. preserved meat	=	1 lb. salt beef or pork.
1 lb. flour, bread, or biscuit or $\frac{1}{2}$ lb. beef or pork	=	$1\frac{1}{4}$ lb. oatmeal or 1 lb. rice or 1 lb. peas.
1 lb. rice	=	$1\frac{1}{4}$ lb. oatmeal.
$\frac{1}{4}$ lb. preserved potatoes	=	1 lb. potatoes.
10 ounces currants	=	8 ounces raisins.
$3\frac{1}{2}$ ounces cocoa or coffee	=	2 ounces tea.
$\frac{3}{4}$ lb. treacle	=	$\frac{1}{2}$ lb. sugar.
1 gill mixed pickles	=	1 gill vinegar.

In some small ships, particularly coasters, a system prevails of giving pay in lieu of food ; this is bad, inasmuch as the men have neither proper storage

for their provisions nor often enough money to provide themselves with food sufficient or of adequate quality.

In cases where the food or water supplied on board a merchant ship is deemed to be either bad or insufficient, any three or more of the crew may complain to any officer in command of any of His Majesty's ships, or to any British Consular Officer, or to a superintendent or a chief Officer of Customs, who, after examining the food or water and finding it defective, must signify the same in writing to the master of the ship ; in case of failure to provide proper provisions, &c., in place thereof, the master is liable to a penalty of £20.

The provisions for the crews of passenger ships are not to be inferior to those of the passengers. The table on page 968 illustrates the scales of dietary authorised by the Board of Trade for passengers ; these scales, it will be observed, vary according to the length of the voyage.

In the case of failure to supply issues of good and wholesome provisions in accordance with the above scales, the master is liable to a penalty of £50.

On board troopships special dietary scales are authorised. These are given in detail, for men, women and children respectively, on pages 970 and 971. The mean nutritive daily value of those for adults may be taken to be :—Proteins, 3·5 ounces ; fats, 1·5 ounce ; carbo-hydrates, 13 ounces ; salts, 1·5 ounce. Boys of 10 years and under 14 years of age receive the woman's ration ; boys of 14 years of age or upwards receive the man's ration ; girls of 10 years of age or upwards receive the woman's ration.

As the outcome of the Report of a recent Committee,* the scale of victualling in His Majesty's Navy has been materially changed and, in principle, accords closely with that which has been found to work well in the land forces. The sailor's ration consists of a standard Government ration, supplemented by a messing allowance of 4*d.* *per diem.* The messing allowance is available, not only for expenditure on luxuries in the canteen, but also for taking up Government provisions on board, in addition to the standard ration. The standard ration, without the messing allowance, is equivalent to the expression "victualling at two-thirds" as defined in Article 1669 of the King's Regulations.

The Standard Ration is intended to represent the ordinary daily requirements of the men in respect of the staple articles of diet ; for service afloat it consists of the following items :—(*a*) 1 lb. bread, or $\frac{3}{4}$ lb. bread and $\frac{1}{4}$ lb. trade flour, (*b*) $\frac{1}{2}$ lb. fresh meat, (*c*) 1 lb. fresh vegetables, (*d*) $\frac{1}{8}$ pint spirit, (*e*) 4 ounces sugar, (*f*) $\frac{1}{2}$ ounce tea or 1 ounce coffee for each $\frac{1}{4}$ ounce of tea, (*g*) $\frac{1}{2}$ ounce soluble chocolate or 1 ounce coffee, (*h*) $\frac{3}{4}$ ounce condensed milk, (*i*) 1 ounce jam or marmalade, (*j*) 4 ounces preserved meat on *one* day of the week in harbour, or on *two* days at sea, (*k*) mustard, pepper, vinegar, and salt as required.

For shore establishments and depôt ships, the same ration (*a* to *k*) is issued with the following modifications :—(*h*) $\frac{1}{4}$ pint fresh milk in place $\frac{3}{4}$ ounce condensed milk, (*j*) no issue of preserved meat.

For boys and youths under training afloat, the ordinary standard ration with the messing allowance of 4*d.* *per diem.* is issued, but with the addition of $\frac{1}{4}$ lb. fresh meat daily or $\frac{1}{4}$ lb. salt pork or preserved meat, 3 ounces ; also in place of $\frac{1}{2}$ ounce tea, $\frac{3}{8}$ ounce tea together with $\frac{3}{4}$ ounce coffee as a break fast ration.

In case it should be necessary to issue substitutes for any of the articles

* Report of the Committee appointed to inquire into the Question of the Canteen and Victualling Arrangements in His Majesty's Fleet, 1907.

TRANSPORT OR TROOPSHIP DIETARIES.

Troops or Third-Class Passengers.

SCALE OF RATIONS per Man.

Days of the Week.	Daily.														Weekly.				
	Salt Beef.	Flour.	Suet.	Raisins.	Salt Pork.	Split Peas.	Preserved Meat.	Compressed Mixed Vegetables.	With Fresh Meat an additional 4 ounces of Bread, or 3 ounces of Biscuit, is to be issued to each Man. Biscuit.	Fresh Bread.	Rice.	Preserved Potatoes (uncooked).	Sugar (unrefined).	Tea.	Vinegar.	Mustard.	Pickles (of various descriptions).	Pepper (ground).	Salt.
	oz.	oz.	oz.	oz.	oz.	pint.	oz.	oz.	oz.	lb.	oz.	oz.	oz.	oz.	pint.	oz.	oz.	oz.	oz.
Sunday	12	6	1	2	—	—	—	—	12	—	—	2	4	$\frac{1}{2}$					
Monday	—	—	—	—	—	—	12	—	—	1	4	—	2	$\frac{1}{2}$					
Tuesday	—	—	—	—	12	$\frac{1}{3}$	—	1	12	—	—	—	2	$\frac{1}{2}$					
Wednesday	12	6	1	2	—	—	—	—	—	1	—	2	4	$\frac{1}{2}$	$\frac{1}{6}$	$\frac{1}{2}$	6	$\frac{1}{6}$	2
Thursday	—	—	—	—	—	—	12	—	12	—	—	2	2	$\frac{1}{2}$					
Friday	—	—	—	—	12	$\frac{1}{3}$	—	1	—	1	—	—	2	$\frac{1}{2}$					
Saturday	—	—	—	—	—	—	12	—	—	1	—	2	2	$\frac{1}{2}$					

SCALE OF RATIONS per Woman.

Days of the Week.	Salt Beef.	Flour.	Suet.	Raisins.	Salt Pork.	Split Peas.	Preserved Meat.	Compressed Mixed Vegetables.	Biscuit.	Fresh Bread.	Rice.	Preserved Potatoes (uncooked).	Sugar (unrefined).	Tea.	Vinegar.	Mustard.	Pickles (of various descriptions).	Pepper (ground).	Salt.
Sunday	8	6	1	2	—	—	—	—	With fresh meat each woman is to receive an additional 4 oz. of bread.	$\frac{3}{4}$	—	2	4	$\frac{1}{2}$					
Monday	—	—	—	—	—	—	8	—		$\frac{3}{4}$	4	—	2	$\frac{1}{2}$					
Tuesday	—	—	—	—	8	$\frac{1}{3}$	—	1		$\frac{3}{4}$	—	—	2	$\frac{1}{2}$					
Wednesday	8	6	1	2	—	—	—	—		$\frac{3}{4}$	—	2	4	$\frac{1}{2}$	$\frac{1}{6}$	$\frac{1}{2}$	6	$\frac{1}{6}$	2
Thursday	—	—	—	—	—	—	8	—		$\frac{3}{4}$	—	2	2	$\frac{1}{2}$					
Friday	—	—	—	—	8	$\frac{1}{3}$	—	1		$\frac{3}{4}$	—	—	2	$\frac{1}{2}$					
Saturday	—	—	—	—	—	—	8	—		$\frac{3}{4}$	—	2	2	$\frac{1}{2}$					

TRANSPORT OR TROOPSHIP DIETARIES—*continued.*

Days of the Week.	SCALE OF RATIONS per Child of 5 Years and under 10 Years of Age. Daily. Salt Pork or Salt Beef.	Flour.	Suet.	Raisins.	Soup and Bouilli.	Rice.	Preserved Meat.	Fresh Bread.	Preserved Potatoes (uncooked).	Sugar.	Tea.	Fresh Milk.	Weekly. Salt.	SCALE OF RATIONS per Child of 1 and under 5 Years of Age. Daily. Biscuits or Rusks.	Sugar.	Fresh Milk.	Soup, Bouilli, or Essence of Beef.	Rice or Oatmeal.	Fresh Bread.
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	lb.	oz.	oz.	oz.	pint.	oz.	oz.	oz.	pint.	pint. Sufficient to make	oz.	oz.
Sunday	6	3	½	2	—	2	—	½	—	3	¼	½		½	2	2	½	4	¼
Monday	—	—	—	—	—	—	4	½	2	2	¼	½		½	2	2	½	4	¼
Tuesday	—	—	—	—	10	2	—	½	—	2	¼	½		½	2	2	½	4	¼
Wednesday	6	3	½	2	—	—	—	½	1	3	¼	½	1	½	2	2	½	4	¼
Thursday	—	—	—	—	—	—	4	½	2	2	¼	½		½	2	2	½	4	¼
Friday	—	—	—	—	10	2	—	½	—	2	¼	½		½	2	2	½	4	¼
Saturday	—	—	—	—	—	—	4	½	2	2	¼	½		½	2	2	½	4	¼

Note.—Each infant under one year of age to be provided with milk, corn-flour, sago or arrowroot and sugar at discretion of Medical Officer.

If condensed milk be used, sufficient to make half a pint for children over five years of age, and sufficient to make 2 pints for children over one but under five years of age.

In using soup and bouilli, it is reckoned that 5½ ounces may be cooked with ¼ pint of water.

In using essence of beef ⅓ of a quarter-pint canister should be cooked with half a pint of water, and mutton broth 4 ounces with a sufficient quantity of boiling water will make the half-pint required.

in this scale of victualling, the following proportion is to be adopted, viz. :— $\frac{1}{2}$ lb. of new type of biscuit or 1 lb. flour for soft bread issue. For fresh vegetables, 1 ounce compressed vegetables or an equivalent quantity of haricot beans or marrowfat peas. When fresh meat is not available, the following will be issued on alternate days :—either (1) $\frac{1}{2}$ lb. salt pork, $\frac{1}{4}$ lb. of split peas, $\frac{1}{2}$ ounce celery-seed to every 8 lb. of split peas put into the coppers, and $\frac{1}{2}$ lb. potatoes or 1 ounce compressed vegetables ; or (2) 6 ounces preserved meat, 8 ounces flour, $\frac{3}{4}$ ounce suet, 2 ounces raisins, and $\frac{1}{2}$ lb. potatoes or 1 ounce compressed vegetables. In place of the flour, suet and raisins, 4 ounces of rice may be issued.

The following scales are the cell diets for men under punishment :—

(*a*) Low diet, consisting of biscuit, 1 lb., and water *ad lib.* ; (*b*) full diet, consisting of biscuit, 10 ounces, fresh vegetables, 8 ounces, or compressed, 1 ounce, tea, $\frac{1}{8}$ ounce, chocolate, $\frac{1}{2}$ ounce, and sugar, $1\frac{1}{2}$ ounce. These are obviously daily issues.

Disease, Accident, and Death at Sea.—The statistical facts at our disposal in respect of these matters are not very satisfactory. While those having reference to the Royal Navy may be deemed fairly complete, those relating to the mercantile marine are far from reliable ; this arises from the fact that many merchant vessels do not carry a surgeon, and that in many cases the information respecting both sickness and death is derived from unprofessional sources.

The average force afloat in the Royal Navy in 1905 was 111,020. The invaliding ratio was 23·89 per 1000, while the death-rate was 3·9 per 1000. The total number entered on the sick list was in the ratio of 734·7 per 1000, and the average number sick daily was 3365·5 or a trifle over 30 per 1000 of strength. Of the 433 deaths, 305 were due to disease and 128 from injuries ; the death-rate due to disease alone was 2·74 and that due to injuries was 1·15 per 1000.

A summary of the mortality in the Royal Navy during recent years is given below :—

Year.	Death-rate per 1000.			Year.	Death-rate per 1000.		
	All Causes.	Disease.	Violence.		All Causes.	Disease.	Violence.
1890	8·5	4·1	4·4	1898	4·90	3·60	1·30
1891	6·2	4·7	1·5	1899	5·41	3·87	1·54
1892	5·6	4·4	1·2	1900	7·26	4·96	2·30
1893	11·3	4·1	7·2	1901	5·34	3·38	1·36
1894	5·8	4·0	1·8	1902	5·92	3·51	2·41
1895	6·6	4·6	2·0	1903	4·19	2·79	1·40
1896	5·3	4·0	1·3	1904	4·50	3·14	1·36
1897	5·2	3·8	1·4	1905	3·90	2·70	1·20

When we come to analyse the statistics of sickness and mortality of seafaring people, we find that sea life is apt to give rise to certain ailments which are more or less characteristic of, or peculiar to, the sailor's surroundings. Thus, sea-sickness is an ailment of marine life only, while formerly scurvy was especially associated with life on board ship. Cholera and yellow fever are diseases closely connected with ships ; the contagion of both being not infrequently carried by them from one country to another.

The chief ailments to which sailors as a class are subject are constipation, boils, erysipelas, lymphangitis, ennui, diarrhœa, sea-sickness, nostalgia, melancholia, hypochondriasis, colic, scurvy, the contagious fevers, itch,

the effects of vicissitudes of climate, catarrhs, rheumatism, dysentery, and venereal affections.

Many of these are of exceptional prevalence, while one or two, notably scurvy and dysentery, are so much the effect of faulty dietaries, that attention to the food-supply of sea-going ships has practically removed these causes of death from the sea-casualty returns.

	Cases.		Invalided.		Dead.		Daily Sick.	
	1897–1904	1905	1897–1904	1905	1897–1904	1905	1897–1904	1905
Small-pox	0·18	0·01	—	—	0·01	—	0·02	—
Other eruptive fevers	9·51	4·86	0·01	0·01	0·06	0·05	0·62	0·25
Influenza	21·75	23·75	0·01	0·01	0·03	—	0·51	0·52
Diphtheria	0·23	0·22	—	0·03	0·01	0·01	0·01	0·02
Cerebro-spinal fever	0·06	0·03	—	0·01	0·05	—	—	—
Enteric fever	2·54	1·72	0·41	0·29	0·49	0·22	0·37	0·27
Malta fever	4·13	3·33	1·85	2·44	0·06	0·09	0·64	0·75
Other continued fevers	17·95	6·36	0·09	0·02	—	—	0·41	0·13
Cholera	0·02	—	—	—	0·01	—	—	—
Dysentery	1·64	0·67	0·23	0·06	0·10	0·04	0·13	0·05
Yellow fever	0·02	—	—	—	—	—	—	—
Malarial fevers	15·00	4·74	0·71	0·16	0·08	0·01	0·50	0·15
Septic diseases	0·54	0·44	—	—	0·06	0·06	0·03	0·02
Tubercular diseases	3·47	3·50	2·60	3·04	0·50	0·36	0·54	0·59
Chancroid	—	10·57	—	—	—	—	—	0·55
Syphilis, primary	37·12	24·58	—	0·07	—	—	3·03	1·93
„ secondary	23·96	24·34	1·51	1·13	0·05	0·02	2·38	2·31
Gonorrhœa	63·25	62·00	0·53	0·67	—	—	3·73	3·42
Alcoholism	0·88	1·06	—	--	0·02	0·01	0·02	0·02
Rheumatism	29·43	19·92	1·23	0·90	0·03	0·03	1·43	1·03
Nervous system	10·64	8·21	3·32	2·65	0·23	0·15	0·75	0·63
Circulatory system	6·15	5·97	2·96	2·39	0·33	0·31	0·56	0·56
Respiratory system	100·17	77·25	2·40	1·13	0·78	0·60	3·15	2·28
Digestive system	128·95	108·67	3·22	2·45	0·23	0·27	2·94	2·80
Diseases of eye	9·12	8·54	1·32	1·05	—	—	0·43	0·35
Poisons	0·91	0·92	0·02	0·03	0·01	0·05	0·02	0·03
Injuries, general	3·33	2·98	0·08	0·18	1·24	0·86	0·06	0·06
„ local	161·81	150·63	1·59	1·68	0·20	0·17	4·45	4·94
Suicide	0·11	0·11	—	—	0·11	0·11	—	—

Some of the disorders prevalent among seamen appear to be closely associated with their duties. Thus, men engaged in the interior of ships, such as cargo-men, cooks, bakers, and storekeepers, are commonly anæmic and debilitated; so too are painters, who, like their fellow workers on shore, are apt to suffer from colic and other symptoms of lead poisoning. Look-out men are said to suffer from weak sight, amblyopia, circumorbital pains, and loss of visual accommodation. Steersmen are liable to accidents from the wheel, and often suffer from auditory troubles, presumably effects of exposure, and prolonged efforts to keep on the alert for signals and words of command. Men engaged aloft generally suffer from traumatic lesions of the hands, feet, and inner parts of the thighs and legs; also from cardiac hypertrophy and hernia, the results of violent exertion. Boatmen and fishermen suffer much from rheumatism and other effects of frequent wettings and long exposure to weather. Boiler-cleaners are liable to asphyxia, while firemen, stokers, and engine-room officers, who constantly work under conditions of high temperature, are usually anæmic, debilitated, and subject to vertigo, stupor, or convulsions. Phthisis is also common among these men. Firemen and stokers, as a class, are often morbid and prone to suicide.

Statistics showing the general prevalence of these and other forms of

illness in the mercantile marine are unfortunately non-existent. How far these diseases and injuries prevail in the Royal Navy are shown in the foregoing Table, prepared from the Statistical Report on the Health of the Navy, and based on the average ratios for the eight years 1897–1904 and for the year 1905.

Mercantile Marine.—That even this service has shared in the general reduction of death-rates which so peculiarly characterises this generation is shown in the following summary of the number and mortality of seamen employed in vessels registered in the United Kingdom under the Merchant Shipping Acts :—

Year.	Persons Employed.	Deaths Reported.	Death-rate per 1000.	Year.	Persons Employed.	Deaths Reported.	Death-rate per 1000.
1891	214,427	3039	14·2	1899	219,383	2857	13·0
1892	218,247	3320	15·2	1900	221,107	2735	12·4
1893	219,560	2678	12·2	1901	224,545	2781	12·4
1894	218,317	3143	14·4	1902	225,443	2625	11·6
1895	217,794	2938	13·5	1903	230,161	2385	10·4
1896	218,224	3067	14·1	1904	233,482	2252	9·6
1897	219,233	2633	12·0	1905	227,430	2096	9·2
1898	218,016	2193	10·1	1906	226,234	2036	9·0

The improvement in the rate of mortality shown in the foregoing Table is due mainly to reductions of deaths on steam-vessels. No returns are issued by the Board of Trade relative to non-fatal forms of sickness among seamen. The chief source of loss of life at sea is due to wreck, drowning, or accident. The exact proportions of these losses in the mercantile marine are shown in the following Table having reference to the year 1906. The figures indicate :—

Class of Vessel.	By Wrecks of, or by Casualities to, the Vessels.	By other Accidents.	By Disease.	Total Losses by Death.	No. of Masters and Seamen Employed.	Death-rate per 1000 from Disease.
Sailing (mercantile) vessels .	61	24	21	106	26,708	0·78
„ (fishing) „ .	286	243	22	551	5,558	3·9
Steam (mercantile) „ .	308	333	643	1284	176,697	3·6
„ (fishing) „ .	41	35	19	95	17,271	1·9
Total . .	696	635	705	2036	226,234	3·1

That in spite of the general unfavourable hygienic conditions which prevail in ships, the health of the mercantile marine, as evidenced by mere death-rates, is good. Two-thirds of the mortality among these men is due to casualties, the result of wrecks and other accidents.

APPENDIX

Measures of Length.

THE **Standard Metre** is $\frac{443296}{864000}$ of the distance, at the temperature of 16°·3 C., between the ends of a certain bar, called the "Toise of Peru," kept in the French Archives, and is approximately the ten-millionth part of the distance from one of the earth's poles to the Equator, at the meridian of Paris. This measure, and those founded on it, is lawful in this country, and a copy of the standard metre is kept in the Exchequer Office at Westminster.

The English **Standard Yard** is the distance, at the temperature of 62° F., between two marks on a certain bar which is kept in the Office of the Exchequer.

The relative values of the Metric and English measures of length can be gathered from the following Table :—

	Metres.	Inches.	Feet.	Yards.	Miles.
Kilometre	1000	—	—	—	0·6214
Hectometre	100	—	—	—	—
Decametre	10	—	—	—	—
Metre	1	**39·37**	**3·28**	**1·0936**	—
Decimetre	0·1	—	—	—	—
Centimetre	0·01	—	—	—	—
Millimetre	0·001	0·03937	—	—	—

Measures of Area.

	Square Metres.	British Measures of Area.	
Square Kilometre	1,000,000	0·3861	sq. mile.
,, Hectometre, or Hectare .	10,000	2·4711	acres.
,, Decametre, or Are . .	100	119·6	sq. yards.
,, **Metre**	1	**10·764**	sq. feet.
,, Decimetre	0·01	15·5	sq. inches.
,, Centimetre	0·0001	0·155	,,
,, Millimetre	0·000001	0·00155	,,

Solid Measures.

1 Cubic Decametre, or Kilostere,	equals	35,316·5	cubic feet.
,, **Metre**, or **Stere**	,,	**35·316**	,,
,, Decimetre, or Millistere	,,	61·025	cubic inches.
,, Centimetre	,,	0·061	,,
,, Millimetre	,,	0·000061	,,

Measures of Weight.

The metric **Standard Kilogramme** is the weight, at the temperature of the maximum density of water (4° C.), and under the atmospheric pressure of 760 millimetres of mercury, in the latitude of Paris, of a certain piece of platinum which is kept in the French Archives. A copy of this

standard kilogramme is kept in our Exchequer Office. The kilogramme was at first intended to be the weight of one cubic decimetre of pure water at its maximum density, but it is in actual fact slightly greater.

The English **Standard Pound Avoirdupois** is the weight, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury, in the latitude of London, and at or near the level of the sea, of a certain piece of platinum which is kept in the Exchequer Office at Westminster.

The relative values of the Metric and English weights is shown in the following Table :—

	Grammes.	Grains.	Avoir. oz.	Avoir. lb.
Kilogramme	**1000**	**15,432**	**35·3**	**2·204**
Hectogramme	100	—	—	—
Decagramme	10	—	—	—
Gramme	1	15·432	0·0353	0·0022
Decigramme	0·1	—	—	—
Centigramme	0·01	—	—	—
Milligramme	0·001	0·0154	—	—

Measures of Capacity.

The metric **Standard Litre** is the volume of a kilogramme of pure water at its temperature of maximum density (4° C.), and under the atmospheric pressure of 760 millimetres of mercury. It was originally intended to be a cubic decimetre, but is actually a little greater. Under the above-mentioned conditions, a litre of pure water weighs one kilogramme.

The English **Standard Gallon** is the volume of 10 lb. avoirdupois of pure water, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury.

The relative values of the Metric and English measures of capacity is shown in the following Table :—

	Cubic centimetres.	Fluid oz.	Pints.	Gallons.	Cubic in.
Kilolitre	1,000,000	—	—	—	—
Hectolitre	100,000	—	—	—	—
Decalitre	10,000	—	—	—	—
Litre	**1000**	**35·3**	**1·76**	**0·22**	**61·027**
Decilitre	100	—	—	—	—
Centilitre	10	—	—	—	—
Millilitre	1	—	—	—	—

Table of Factors for Calculating Equivalents of Weight, Volume, Length, &c.

To convert grammes	to pounds	multiply by	0·0022
,, ,,	to grains	,,	15·432
,, ,,	to ounces	,,	0·0353
,, grains	to grammes	,,	0·0648
,, ounces	to ,,	,,	28·349
,, pounds	to ,,	,,	453·715
,, kilogrammes	to pounds	,,	2·204
,, ,,	to ounces	,,	35·3

To convert litres	to gallons	multiply	0·22
" "	to fluid ounces	"	5·3
" "	to pints	"	1·76
" "	to cubic feet	"	0·0354
" "	to cubic inches	"	61·027
" gallons	to cubic feet	"	0·1605
" "	to litres	"	4·5371
" pints	to "	"	0·5679
" "	to cubic centimetres	"	568·1818
" "	to cubic inches	"	34·6592
" cubic metres	to gallons	"	220·4
" "	to pints	"	1763·2
" "	to fluid ounces	"	35264·0
" cubic feet	to cubic metres	"	0·0283
" "	to litres	"	28·318
" "	to gallons	"	6·2322
" fluid ounces	to cubic inches	"	1·7299
" "	to cubic centimetres	"	28·35
" square feet	to square metres	"	0·0929
" "	to square yards	"	0·111
" square metres	to square feet	"	10·7641
" inches	to metres	"	0·0254
" "	to millimetres	"	25·4
" metres	to inches	"	39·37
" "	to feet	"	3·28
" feet	to miles	"	0·000187
" "	to metres	"	0·3048
" yards	to miles	"	0·00057
" "	to centimetres	"	91·44
" centimetres	to inches	"	0·3937
" millimetres	to "	"	0·03937
" kilometres	to miles	"	1·6
" square kilometres	to square miles	"	2·5899
" hectares	to acres	"	0·4046

The Chemical Symbols and Atomic Weights of Elementary Bodies.

Names of Elements.	Chemical Symbols.	Atomic Weights.	Names of Elements.	Chemical Symbols.	Atomic Weights.
Aluminium	Al	27·5	Nitrogen	N	14·0
Antimony	Sb	120·0	Oxygen	O	16·0
Arsenic	As	75·0	Palladium	Pd	105·7
Barium	Ba	137·0	Phosphorus	P	31·0
Bromine	Br	80·0	Platinum	Pt	197·2
Cadmium	Cd	112·0	Potassium	K	39·0
Calcium	Ca	40·0	Rubidium	Rb	85·3
Carbon	C	12·0	Selenium	Se	78·8
Chlorine	Cl	35·5	Silicon	Si	28·0
Chromium	Cr	52·5	Silver	Ag	108·0
Cobalt	Co	59·0	Sodium	Na	23·0
Copper	Cu	63·2	Strontium	Sr	87·4
Fluorine	F	19.0	Sulphur	S	32·0
Gold	Au	196·2	Tantalum	Ta	182·0
Hydrogen	H	1·0	Tellurium	Te	125·0
Iodine	I	126·6	Thallium	Tl	203·7
Iridium	Ir	192·7	Thorium	Th	231·5
Iron	Fe	56·0	Tin	Sn	118·0
Lead	Pb	206·5	Titanium	Ti	48·0
Lithium	Li	7·0	Tungsten	W	184·0
Magnesium	Mg	24·0	Uranium	U	240·0
Manganese	Mn	55·0	Vanadium	V	51·3
Mercury	Hg	200·0	Yttrium	Y	88·0
Molybdenum	Mo	95·5	Zinc	Zn	65·0
Nickel	Ni	59·0	Zirconium	Zr	89·4

Table showing Weights of Service Pipes required by various Water Companies (in lb. per lineal yard).

Name of Water Company.	Diameter of Pipe in Inches.					
	3/8	1/2	5/8	3/4	1	1¼
London Water Board	5	6	7½	9	12	16
Manchester Corporation	—	6	—	9	12	16
Glasgow (Loch Katrine)	—	7	—	10	14	18
Sheffield	5	7	9	11	16	22½
Norwich	5	7	9	11	16	22½
Market Harborough	5	6	7½	11	16	20
Kent	—	5	7	9	12	—
West Surrey	4	5½	—	9	14	20
Caterham	5	6	8	10	14	—
Colne Valley	5	7	9	11	16	—
Sevenoaks and Tonbridge	—	5	7	9	12	15

Table of Fall necessary to obtain certain Velocities (in feet per second) in Drains running full or half-full.

Diam. of Drain in Inches.	V=2·5	V=3	V=3·5	V=4	V=4·5	V=5	V=5·5	V=6
	1 in	1 in	1 in	1 in	1 in	1 in	1 in	1 in
4	129	92	68	53	42	34	29	24
5	161	115	85	66	52	42	36	30
6	193	137	102	80	62	51	43	36
9	290	206	154	119	95	77	65	54
12	386	275	205	159	127	103	86	72

Relative Discharging Power of Pipes.

When the fall and length of the pipes remain constant, the discharge varies as the square root of the fifth power of the diameter.

PREPARATION OF CULTURE MEDIA.

A variety of culture media have been alluded to in the text, particularly in the section which deals with the bacteriological examination of a water sample. The manner of preparing but one has been given in detail, namely, the bile-salt-glucose broth used in MacConkey's method. Details as to some other media in common use are given below.

Nutrient Broth.—One pound of meat, free from fat, must be minced finely, then infused in a litre of cold distilled water, and allowed to stand in a cold place for twenty-four hours. The whole mass is then strained through a cloth, and distilled water added to the filtrate so as to make up the volume of fluid to one litre. Ten grammes of peptone and five grammes of common salt are now added to the litre of fluid, which is then boiled in the steam steriliser for one hour at 100° C. Owing to the presence of acid phosphates of potassium and sodium, weak acids of the glycolic series, and organic compounds in which the acid character predominates, this meat extract will be more or less acid. It will always react acid to phenolphthalein, but occa-

sionally reacts neutral or even alkaline to litmus. Further, if exactly neutral to litmus, it will be found to react acid to phenolphthalein. The main reason for this is due to the fact that litmus is insensitive to many weak organic acids, the presence of which is readily indicated by phenolphthalein. Estimate the reaction of the medium by placing 25 c.c. of it into a clean beaker, running in 0·5 c.c. of phenolphthalein solution, immersing the beaker in a water-bath, and raising to the boil. Now, cautiously, run into the medium in the beaker, standing in the water-bath at the boil, some $\frac{N}{10}$ NaOH solution, until the end point is reached as indicated by the development of a faint pink tinge. Note the amount of deci-normal soda solution used. It is convenient to use broth media standardised to + 10, the symbol + meaning acid, and – meaning alkaline, in both cases to phenolphthalein as indicator. Briefly, the method of standardising a litre of broth or other medium to + 10 consists in subtracting 10 from the initial *titre* of the medium mass; the remainder indicates the number of cubic centimetres of normal soda solution that must be added to the medium, per litre, to render the reaction + 10. Say 25 c.c. of the medium have required the addition of 5·65 c.c. $\frac{N}{10}$ NaOH solution to neutralise it, and therefore 1000 c.c. will require 226 c.c. or 22·6 c.c. of $\frac{N}{1}$ NaOH solution. The initial *titre*, then, of this medium will be + 22·6, and as such requires the addition of (22·6 – 10) 12·6 c.c. of normal NaOH per litre to leave its finished reaction at + 10. To be strictly accurate, allowance must be made for the volume of medium used in the titrations, and remembrance made that the remainder of medium to be neutralised does not now measure a full litre. Say three titrations were made, each with 25 c.c., then the original bulk of the medium will be but 925 c.c., requiring but 11·65 c.c. of normal NaOH to make it + 10.

Having brought the medium to the required reaction, heat again for half an hour at 100° C., to complete the precipitation of phosphates. Filter through Swedish filter-paper into sterile tubes (10 c.c. in each). Plug the tubes with cotton-wool, and then sterilise these in the steamer on three successive days for twenty minutes.

Glucose and Lactose Broth.—These are simply the above ordinary broths, containing 1 or 2 per cent. of either grape- or milk-sugar. The steps in the preparation are the same as those just described.

Nutrient Gelatin.—This is made by adding 10 to 15 per cent. of gold-labelled gelatin, cut into small pieces, to ordinary broth prepared as above, and then melting it by steaming at 100° C. for one hour. Estimate the reaction of the medium mass, as explained for broth, then add sufficient normal soda solution to render the reaction of the calculated bulk of medium + 10. Replace in the steamer, and keep at 100° C. for twenty minutes to precipitate all phosphates. Allow to cool to 60° C. Add the whites of two eggs for each litre of medium, replace in steamer at 100° C. for half an hour; then filter through Chardin paper into sterile tubes. Sterilise these at 100° C. for twenty minutes on each of three consecutive days.

Glucose and Lactose Gelatin are made in the same way, adding 1 to 2 per cent. of the respective sugars.

Nutrient Agar-agar.—Add fifteen grammes of agar, cut into very fine fragments, to a litre of ordinary broth, prepared as explained. Dissolve by heating at 100° C. for an hour and a half. Estimate the reaction of the medium mass as explained under the head of "Broth"; then add sufficient

normal soda solution to render the reaction of the calculated bulk of the medium + 10. Replace in the steamer for twenty minutes to complete the precipitation of phosphates. Allow the medium to cool to 60° C., add whites of two eggs, replace in steamer, and keep at 100° C. for half an hour. Now filter through Chardin paper, by the aid of a hot-water funnel, into sterile tubes. Sterilise in steamer at 100° C. for half an hour on each of three successive days.

Glycerin-agar is made in the same way, 6 per cent. of glycerin being added after filtration.

Glucose and Lactose Agar are made as under ordinary agar, 2 per cent. of the respective sugars being added, as the case may be. If required to be tinted with neutral red, 2 per cent. of a half per cent. solution of neutral red is added before filtration.

Peptone Solution.—One to two per cent. of Witte's peptone with 0·5 per cent. of common salt are dissolved in distilled water by heating. The fluid is then filtered, placed in tubes, and sterilised. In this medium, cholera vibrios grow with great rapidity. It is also much used for testing the formation of indol by different bacteria.

Glucose-peptone Solution.—Made by dissolving, by means of heat, 1 gramme of glucose, 1 gramme of peptone, and 0·5 gramme of salt in 100 c.c. of distilled water. This is filtered, rendered neutral to litmus, placed in steamer at 100° C. for half an hour, then tubed into test-tubes containing inverted fermentation tubes, and sterilised for twenty minutes at 100° C. on three successive days.

Lactose-peptone Solution.—Prepared as the foregoing, substituting lactose for the glucose.

Sucrose, Mannite, Dulcite, Raffinose and other carbohydrate or glucoside **Peptone Solutions** are prepared as the foregoing, substituting the corresponding constituent.

Proskauer and Capaldi's Media.—The No. 1 medium has the following composition :—Asparagin and mannite, of each 0·2 per cent. ; potassium mono-phosphate, 0·2 per cent. ; sodium chloride and calcium chloride, of each 0·02 per cent. ; and of magnesium sulphate, 0·01 per cent. The reagents are dissolved in distilled water, sterilised for an hour at 100° C. The medium is then rendered neutral to litmus by the addition of sufficient normal caustic soda solution. Sufficent litmus solution is added to give the medium a purple tint. It is now tubed and sterilised in the usual way for twenty minutes at 100° C. on three successive days.

The No. 2 medium contains 2 per cent. of Witte's peptone and 0·1 per cent. of mannite dissolved in distilled water. Sterilised at 100° C. for an hour, this will now be found to be alkaline ; it is next carefully rendered neutral to litmus by the addition of a saturated solution of citric acid. Litmus solution is added to give it a deep red colour. It is now tubed and sterilised in the usual way for twenty minutes at 100° C. on three successive days. These media are of great value in the differential diagnosis between the *B. coli* and the *B. typhosus*.

Milk.—Fresh milk and free from any preservative is steamed for half an hour at 100°, and then placed in a cool place over night for separation of cream. The milk is then syphoned off from beneath the cream, and placed in sterile tubes ; if necessary, sufficient litmus solution is added to give it a purple tinge. The tubes are plugged, and then sterilised at 100° C. for twenty minutes on each of three successive days.

Potato Medium.—A large potato is well washed and scrubbed with a brush. A cylinder is then bored from its interior, and cut obliquely. The

peel from the ends is cut off, and the wedges so obtained allowed to soak over night in cold water to get rid of any excess of starch. Each wedge of potato is then placed in a test-tube previously fitted with a pad of cotton-wool at the bottom, and filled for about half an inch in depth with distilled water. The tube is now plugged with cotton-wool, and sterilised at 100° C. for twenty minutes on three successive days.

Drigalski-Conradi Medium. (1) *Agar preparation.*—To 3 lb. of finely cut beef add 2 litres of water; allow the mixture to stand until next day. Boil the expressed meat-juice for one hour and filter; add 20 grammes of Witte's peptone, 20 grammes of nutrose, 10 grammes of sodium chloride, and boil the whole again for an hour and then filter. Now add 70 grammes of agar, boil for three hours, render slightly alkaline to litmus, filter and boil for half an hour. (2) *Litmus solution.*—Take 260 c.c. of either Kubel and Tiemann's litmus solution, or of a purified litmus solution, prepared as explained later; boil for ten minutes; add 30 grammes of lactose and boil for fifteen minutes. Add this hot litmus-lactose solution to the liquid-agar solution and mix; render it faintly alkaline; then add 4 c.c. of a hot sterile solution of 10 per cent. water-free soda and 20 c.c. of a freshly prepared solution of 0·1 gramme crystal violet (Höchst) in 100 c.c. of warm sterile distilled water. The result is a meat-water peptone nutrose agar, containing 13 per cent. litmus and 0·01 per 1000 crystal violet. Tube, and sterilise in steam for thirty minutes. Eyre * has suggested a modified nutrose agar which is equally satisfactory.

Litmus Solution.—For bacteriological work a pure solution of the blue dye (azolitmin) should be used. It is freely soluble in water, but insoluble in alcohol. It can be prepared as follows:—Digest 2 ounces of powdered litmus with fresh quantities of hot water until all the colouring-matter is dissolved out; allow to settle and decant off the fluid. Evaporate this solution down from about a litre to 300 c.c.; add a slight excess of acetic acid; evaporate further over a water-bath until the liquid becomes pasty. Add 200 c.c. of methylated spirit and mix. The spirit precipitates the azolitmin, leaving the red dye in solution. Filter. Wash out dish and filter with methylated spirit. Now dissolve the pure blue colouring-matter on the filter in warm distilled water and dilute to 500 c.c. This azolitmin solution is far more sensitive than ordinary litmus solution.

Neutral-red Bile-salt Agar.—Dissolve 20 grammes of agar in a litre of water in an autoclave; add 5 grammes of sodium taurocholate and 20 grammes of peptone. Clear by means of white of egg in usual way and filter. Now add 10 grammes of lactose and 5 c.c. of a 1 per cent. solution of neutral red. Tube and sterilise for twenty minutes on two successive days. It is best to have the neutral-red solution freshly prepared.

Endo's Fuchsin-agar.—To 1 litre of water add 500 grammes of minced beef, 10 grammes of peptone, 5 grammes of sodium chloride, and 30 grammes of agar. Boil well, filter, and neutralise; then make alkaline by adding 10 c.c. of a 10 per cent. solution of sodium carbonate. Now add 10 grammes of lactose, and 5 c.c. of a 10 per cent. fuchsin solution in 96 per cent. of alcohol. The medium is now a dark red colour. Twenty-five c.c. of a 10 per cent. sodium sulphite solution are now added. The medium gradually decolorises. Tube and sterilise once for half an hour in steam. On this medium, colonies of *B. coli* are red, those of *B. typhosus* are colourless and transparent. The finished medium should be kept in the dark, otherwise it turns red. Gachtgens has suggested a modification of this medium by adding 0·33 per cent. of caffein and giving it an alkalinity equal to

* Eyre: *Trans. Patholog. Soc. London*, vol. lv. p. 91.

1·5 per cent. normal NaOH solution *below* the neutral point of phenolphthalein.

Malachite-green Agar.—Macerate 3 lb. of minced beef in 2 litres of water for twenty hours. Express, boil, filter, add 3 per cent. of agar and boil now for three hours. Add 1 per cent. of peptone, 0·5 per cent. of sodium chloride ; neutralise to the litmus neutral point by soda solution with duplitest paper, boil again for an hour and filter. This finished agar will now be acid. It may now be run into flasks and sterilised in the usual way. Before use and adding the malachite-green, the agar must be melted and made alkaline with sterile soda solution, testing with duplitest paper until the red slip is red-violet. To 100 c.c. of the hot agar add 1 c.c. of a 1 in 60 solution of malachite-green in distilled water. This agar now contains malachite-green 1 in 6000. By this strength, the growth of *B. coli* is diminished. The *B. typhosus* colonies are also retarded, but appear as minute glistening points which subsequently colour the agar yellow.

Alkaline Litmus-glucose Agar.—Prepare ordinary agar with 2 per cent. glucose as already explained. Render neutral to litmus. Run into test-tubes, putting 10 c.c. into each tube. Sterilise. When required for use, melt in water-bath and when at boiling-point run in 1·5 c.c. of neutral litmus solution and 0·92 c.c. of deci-normal alkali. The medium should now have an alkalinity equal to 8 per cent. of deci-normal alkali. *B. coli* colonies on plates of this medium show a rose-red colour, while those of *B. typhosus* are translucent blue points.

TABLE OF LOG. Γ FUNCTIONS.

(*See* page 818.)

P.	0		1	2	3	4	5	6	7	8	9
1·00	—	—	9750	9500	9251	9003	8755	8509	8263	8017	7773
1·01	$\bar{1}$·99	7529	7285	7043	6801	6560	6320	6080	5841	5602	5365
1·02		5128	4892	4656	4421	4187	3953	3721	3489	3257	3026
1·03		2796	2567	2338	2110	1883	1656	1430	1205	0981	0757
1·04		0533	0311	0089	9868	9647	9427	9208	8989	8772	8554
1·05	$\bar{1}$·98	8338	8122	7907	7692	7478	7265	7053	6841	6629	6419
1·06		6209	6000	5791	5583	5376	5169	4963	4758	4553	4349
1·07		4145	3943	3741	3539	3338	3138	2939	2740	2541	2344
1·08		2147	1951	1755	1560	1365	1172	0978	0786	0594	0403
1·09		0212	0022	9833	9644	9456	9269	9082	8896	8710	8525
1·10	$\bar{1}$·97	8341	8157	7974	7791	7610	7428	7248	7068	6888	6709
1·11		6531	6354	6177	6000	5825	5650	5475	5301	5128	4955
1·12		4783	4612	4441	4271	4101	3932	3764	3596	3429	3262
1·13		3096	2931	2766	2602	2438	2275	2113	1951	1790	1629
1·14		1469	1309	1150	0992	0835	0677	0521	0365	0210	0055
1·15	$\bar{1}$·96	9901	9747	9594	9442	9290	9139	8988	8838	8688	8539
1·16		8390	8243	8096	7949	7803	7658	7513	7369	7225	7082
1·17		6939	6797	6655	6514	6374	6234	6095	5957	5818	5681
1·18		5544	5408	5272	5137	5002	4868	4734	4601	4469	4337
1·19		4205	4075	3944	3815	3686	3557	3429	3302	3175	3048
1·20		2922	2797	2672	2548	2425	2302	2179	2057	1936	1815
1·21		1695	1575	1456	1337	1219	1101	0984	0867	0751	0636
1·22		0521	0407	0293	0180	0067	9955	9843	9732	9621	9511
1·23	$\bar{1}$·95	9401	9292	9184	9076	8968	8861	8755	8649	8544	8439
1·24		8335	8231	8128	8025	7923	7821	7720	7620	7520	7420
1·25		7321	7223	7125	7027	6930	6834	6738	6642	6547	6453
1·26		6359	6267	6173	6081	5989	5898	5847	5716	5627	5537
1·27		5449	5360	5273	5185	5099	5013	4927	4842	4757	4673
1·28		4589	4506	4423	4341	4299	4178	4097	4017	3938	3858
1·29		3780	3702	3624	3547	3470	3394	3318	3243	3168	3094
1·30		3020	2947	2874	2802	2730	2659	2588	2518	2448	2379
1·31		2310	2242	2174	2106	2040	1973	1907	1842	1777	1712
1·32		1648	1585	1522	1459	1397	1336	1275	1214	1154	1094
1·33		1035	0977	0918	0861	0803	0747	0690	0634	0579	0524
1·34		0470	0416	0362	0309	0257	0205	0153	0102	0051	0001
1·35	1·94	9951	9902	9853	9805	9757	9710	9663	9617	9571	9325
1·36		9480	9435	9391	9348	9304	9262	9219	9178	9136	9095
1·37		9054	9015	8975	8936	8898	8859	8822	8785	8748	8711
1·38		8676	8640	8605	8571	8537	8503	8470	8437	8405	8373
1·39		8342	8311	8280	8250	8221	8192	8163	8135	8107	8080
1·40		8053	8026	8000	7975	7950	7925	7901	7877	7854	7831
1·41		7808	7786	7765	7744	7723	7703	7683	7664	7645	7626
1·42		7608	7590	7573	7556	7540	7524	7509	7494	7479	7465
1·43		7451	7438	7425	7413	7401	7389	7378	7368	7358	7348
1·44		7338	7329	7321	7312	7305	7298	7291	7284	7278	7273
1·45		7268	7263	7259	7255	7251	7248	7246	7244	7242	7241
1·46		7240	7239	7239	7240	7241	7242	7243	7245	7248	7251
1·47		7254	7258	7262	7266	7271	7277	7282	7289	7295	7302
1·48		7310	7317	7326	7334	7343	7353	7363	7373	7384	7395
1·49		7407	7419	7431	7444	7457	7471	7485	7499	7514	7529

TABLE OF LOG. Γ FUNCTIONS *continued.*

P.	0	1	2	3	4	5	6	7	8	9
1·50	$\bar{1}\cdot 94$ 7545	7561	7577	7594	7612	7629	7647	.7666	7685	7704
1·51	7724	7744	7764	7785	7806	7828	7850	7873	7896	7919
1·52	7943	7967	7991	8016	8041	8067	8093	8120	8146	8174
1·53	8201	8229	8258	8287	8316	8346	8376	8406	8437	8468
1·54	8500	8532	8564	8597	8630	8664	8698	8732	8767	8802
1·55	8837	8873	8910	8946	8983	9021	9059	9097	9135	9174
1·56	9214	9254	9294	9334	9375	9417	9458	9500	9543	9586
1·57	9629	9672	9716	9761	9806	9851	9896	9942	9989	$\bar{0}035$
1·58	$\bar{1}\cdot 95$ 0082	0130	0177	0225	0274	0323	0372	0422	0472	0522
1·59	0573	0624	0676	0728	0780	0833	0886	0939	0993	1047
1·60	1102	1157	1212	1268	1324	1380	1437	1494	1552	1610
1·61	1668	1727	1786	1845	1905	1965	2025	2086	2147	2209
1·62	2271	2333	2396	2459	2522	2586	2650	2715	2780	2845
1·63	2911	2977	3043	3110	3177	3244	3312	3380	3449	3517
1·64	3587	3656	3726	3797	3867	3938	4010	4081	4154	4226
1·65	4299	4372	4446	4519	4594	4668	4743	4819	4894	4970
1·66	5047	5124	5201	5278	5356	5434	5513	5592	5671	5740
1·67	5830	5911	5991	6072	6154	6235	6317	6400	6482	6566
1·68	6649	6733	6817	6901	6986	7072	7157	7243	7322	7416
1·69	7503	7590	7678	7766	7854	7943	8032	8122	8211	8301
1·70	8391	8482	8573	8664	8756	8848	8941	9034	9127	9220
1·71	9314	9409	9502	9598	9693	9788	9884	9980	$\bar{0}077$	$\bar{0}174$
1·72	$\bar{1}\cdot 96$ 0271	0369	0467	0565	0664	0763	0862	0961	1061	1162
1·73	1262	1363	1464	1566	1668	1770	1873	1976	2079	2183
1·74	2287	2391	2496	2601	2706	2812	2918	3024	3131	3238
1·75	3345	3453	3561	3669	3778	3887	3996	4105	4215	4326
1·76	4436	4547	4659	4770	4882	4994	5107	5220	5333	5447
1·77	5561	5675	5789	5904	6019	6135	6251	6367	6484	6600
1·78	6718	6835	6953	7071	7189	7308	7427	7547	7666	7787
1·79	7907	8028	8149	8270	8392	8514	8636	8759	8882	9005
1·80	9129	9253	9377	9501	9626	9751	9877	$\bar{0}003$	$\bar{0}129$	$\bar{0}255$
1·81	$\bar{1}\cdot 97$ 0383	0509	0637	0765	0893	1021	1150	1279	1408	1538
1·82	1668	1798	1929	2060	2191	2322	2454	2586	2719	2852
1·83	2985	3118	3252	3386	3520	3655	3790	3925	4061	4197
1·84	4333	4470	4606	4744	4881	5019	5157	5295	5434	5573
1·85	5712	5852	5992	6132	6273	6414	6555	6697	6838	6980
1·86	7123	7266	7408	7552	7696	7840	7984	8128	8273	8419
1·87	8564	8710	8856	9002	9149	9296	9443	9591	9739	9887
1·88	$\bar{1}\cdot 98$ 0036	0184	0333	0483	0633	0783	0933	1084	1234	1386
1·89	1537	1689	1841	1994	2147	2299	2453	2607	2761	2915
1·90	3069	3224	3379	3535	3690	3846	4003	4159	4316	4474
1·91	4631	4789	4947	5105	5264	5423	5582	5742	5902	6062
1·92	6223	6383	6544	6706	6867	7029	7192	7354	7517	7684
1·93	7844	8007	8171	8336	8500	8665	8830	8996	9161	9327
1·94	9494	9660	9827	9995	$\bar{0}162$	$\bar{0}330$	$\bar{0}498$	$\bar{0}666$	$\bar{0}835$	$\bar{1}004$
1·95	$\bar{1}\cdot 99$ 1173	1343	1512	1683	1853	2024	2195	2366	2537	2709
1·96	288	3054	3227	3399	3573	3746	3920	4094	4269	4443
1·97	4618	4794	4969	5145	5321	5498	5674	5851	6029	6206
1·98	6384	6562	6740	6919	7098	7277	7457	7637	7817	7997
1·99	8178	8359	8540	8722	8903	9085	9268	9450	9633	9816

INDEX

Absorbability of food, 245
Acanthocephala, 604
Acarus farinæ, 307
    scabiei, 609
Accessory foods, 233
Acclimatisation, 840
Accoutrements of soldier, 908
Acetylene, 149
Achorion Schonleini, 570
Acid, boric, in milk, 291
    carbolic as disinfectant, 750
    nitric in water, 77, 93
    nitrous „ 77, 91
    phosphoric in water, 77
    salicylic in milk, 292
    sulphuric in water, 77
    sulphurous as disinfectant, 753
Acids of beer, 341
    bread, 310
    vegetables, 228
    wine, 349
Actinomycosis, 570
Adulteration, law as to, 336
    of arrowroot, 323
        beer, 343
        bread, 310
        butter, 299
        cocoa, 366
        coffee, 363
        flour, 307
        lime-juice, 367
        milk, 289
        tea, 362
        vinegar, 368
        wine, 349
Aerated filters for sewage, 512
Agar-agar, preparation of, 979
Age-incidence of mortality from disease, 794
Air, 132
    amount required, 178
        for animals, 182
            lights, 181
            the sick, 181
    calculation of amount required, 179
    collection of sample of, 166
    diffusion of, 138
    effects of combustion on, 145
        respiration on, 163
        impurities in, 139
        increased pressure of, 838
        suspended matter in, 154
    electrical conditions of, 851
    estimation of carbon dioxide in, 168
        monoxide in, 171
        micro-organisms in, 173
        oxygen in, 166
Air—*continued*.
    estimation of ozone in, 172, 852
        sulphur in, 172
    examination of, 165
    heating of, 204
    humidity of, 855
    impurities of, 139
    movement, 850
    of marshes, 145
        mines, 143
        sewers, 144
    weight of, 137, 858
Air-meters, 221
Albuminoids, 225
Alcohol as an article of diet, 355
    estimation of, 345
Algæ in water, 101
Alkali works, 543
    law relating to, 555
Altitudes, residence at high, 837
Alum as purifier of water, 67
    in beer, 343
        wine, 349
Aluminium process for determination of nitrates, 94
Aluminous precipitants for sewage, 506
Ammonia in air, 134
    water, 87
Amœba dysenteriæ, 571
Amphistomum hominis, 585
Analysis of air, 165
    food, certificate for, 338
    water, 74
Anchylostomum duodenale, 601
Anemometers, 221, 850
Angus Smith's coating for pipes, 52
Animals, cubic space for, 183
    determination of age of, 257
    diseases of, 261
    inspection of, 252
    nuisance from keeping of, 533
    slaughtering of, 534, 557
    water for, 40
Anophelina, 618
Anthomyia canicularis, 623
Anthrax, 638
Anticyclone, 872
Anti microbic serum, 635
Antiseptics, 741
Anti-toxins, 634
Aqueous rocks, 388
    vapour, tension of, 856
Arachnids, parasitic, 605
Argas persicus, 609
    reflexus, 608
Argon, 133

Army sanitation, 883
Arrowroots, 321
Arsenic in trades, 546
Artesian wells, 44
Artificial cooling of air, 217
improvement of wine, 350
manure making, 54
ventilation, 188
Artisans' dwellings, 435
law relating to, 464
Arthropoda, 605
Ascaris lumbricoides, 603
mystax, 603
Ash of milk, 283
Aspergillus, 570
Asses' milk, 272
Atmospheric electricity, 851
pressure, 863
Atomic weights, table of, 977
Aurora, 852
Austrian soldier, food of, 904
Averages and means, 810

Bacillus typhosus in water, 113
methods for detecting, 116
enteritidis of Gärtner, 113
Klein, 123
Bacon-curing, nuisance from, 538
Bacteria in air, 173
water, 103
Bacteriological examination of air, 173
milk, 287
water, 103
Bakehouses, law relating to, 311
Baking, 248
Balantidium coli, 582
Ball-traps, 495
Barff's coating for pipes, 50
Barley, 313
Barometers, 863
Barracks, 885
Baths and wash-houses, law as to, 34
Beans, 319
Bedding, disinfection of, 761
Beef broth, preparation of, for cultures, 978
Beef-extracts, 248, 328
Beer, 339
examination of, 344
Beet-sugar, 325
Beggiatoa in water, 102
Bell filters, 67
Bengalia depressa, 627
Beriberi, 643
Berler system of sewage removal, 503
Beverages and condiments, 339
Bilges of ships, 952
Bilharzia hæmatobia, 585
Biltong, 328
Biological treatment of sewage, 508
Birth-rates, 777
Biscuits, 312
Blastomycetes, 569
Bleaching-powder as disinfectant, 752
Blood, trades involving use of, 534
Boiling of meat, 248
tripe, 535
Bond's Euthermic stove, 212
Bone-boiling, 536
Boots, 378
Boracic acid in milk, 291
Bothriocephalus latus, 592
Botrytis bassiana, 570
Bovril, 328
Boyle's law, 137
Brandy, 352
Brassfounders' ague, 157, 552
Braxy, 255
Bread, 308
Brickfields, effluvia from, 160
Bromine treatment of water, 931
Buckwheat, 318
Building angles, 432
Buildings, law relating to new, 454
Burial Boards, 528
of dead, 527
Butter, 298, 876
law relating to, 302, 876
Buys Ballot's law, 870
Bye-laws, 23
model as to burial-grounds, 528
canal boats, 475
cleansing and scavenging, 484
common lodging-houses, 461
mortuaries, 529
movable dwellings, 476
newstreets and houses, 455
offensive trades, 553
privies and middens, 522
slaughter-houses, 558
tenement-houses, 462

Cabbage, 326
Calcium hypochlorite as disinfectant, 752
purifier of water, 930
Calculation of diets, 243
discharge from pipes, 978
work done, 384
Calories, 234
Calorigen stove, 212
Camps, hygiene of, 917
Canal boats, 474
Candy filters, 68
Cane sugar, 227, 325
in milk, 290
Canna arrowroot, 323
Canned meat, 332
Carbo-hydrates, 226
Carbolic acid, 750
Carbon, amount needed daily, 240
Carbon dioxide in air, 134
elimination of, 179
estimation of, 168
disulphide, effects of, 157
monoxide, effects of, 158
estimation of, 171
Carburetted water gas, 150
Casein, estimation of, 285
Cattle, diseases of, 254
Cellar dwellings, law relating to, 472
Cement works, air of, 160
Cemeteries, law relating to, 527
Ceratophyllus fasciatus, 613
Cercomonas hominis, 572
Cerebro-spinal fever, 645
Cesspits, 504

Chalk, water from, 54
Chamberland-Pasteur filters, 69
Charcoal as filtering medium, 69
Charles' law, 137
Charqui, 328
Charts, meteorological, notation of, 874
Cheese, 303
Chemical works, law relating to, 555
Chicken pox, 648
Chicory, 364
Chittenden's work on metabolism, 239
Chlorine as a disinfectant, 752
purifier of water, 73, 930
in water, 77, 83
Chocolate, 367
Choke-damp, 144
Cholera, 649
regulations as to, 7, 880
spirillum, detection in water, 120
Chrome works, 156, 547
Chrysops distinctipennis, 621
Cisterns, 50
Clark's process for softening water, 65
Clay, water from, 55
Cleansing, law relating to, 484
of persons, 33
Climate, 831
Closets, earth, 483
slop, 488
trough, 490
water, 490
Clothing, 371
of the soldier, 906
Clouds, 859
Coal-gas, 146
Coca, 365
Coccidium hominis, 578
Cocoa, 366
Coefficient of contingency, 827
correlation, 820
phenol, 765
variation, 811
Coffee, 363
Collection of air samples, 166
water samples, 75, 103
-supplies, 48
Colostrum, 275
Cols, 873
Combustion, air vitiated by, 145
Common lodging-houses, 460, 878
Comparison of heating methods, 212
sewage-disposal methods, 515
ventilation methods, 192
Concentrated foods, 327
Condensed milk, 281
Condiments, 368
Conduction, heating by, 205
Constant supply of water, 51
Construction of dwellings, 423
ships, 949
Contagion, 631
Contagious Diseases (Animals) Act, 293
Contingency, theory of, 826
Contour lines, 42
Convection, heating by, 206
Cooking, 246
Cooling of air, 217
Copper in food, 335
water, 99
as a purifier of water, 72
Correlation, theory of, 820
Cotton, 374
Cream, 282
Cremation, 530
Cubic space for animals, 182
in barracks, 889
dwellings, 180
ships, 956
measurement of, 219
relation to ventilation, 183
Culicidæ, 615
Culicina, 618
Culture media, preparation of, 978
Curcuma arrowroot, 322
Curves, frequency, 812
Cuterebra noxialis, 627
Cyclones, 870
Cyllin as a disinfectant, 751
Cysticercus cellulosæ, 255, 587
Cytoryctes, 582

Dairies, cowsheds, law relating to, 293
Damp-proof courses, 424
Death, causes of, 790
mean age at, 809
rates, 780
influence of birth-rate on, 784
urban and rural, 786
Definition of sanitary terms, 21
Dengue, 653
Density of population, 785
Deodorants, 741
Dermacentor reticulatus, 608
Desmids in water, 101
Dew-point, 855
Destructors for refuse, 480
Diarrhœa, epidemic, 655
Diatoms in water, 101
Diet, general principles of, 233
Diets, calculation of, 243
in army, 900
navy, 969
standard, 240
Diffusion of air, 138
Digestibility of food, 245
Diphtheria, 658
relation to milk, 277
sewers, 162
Disaccharids, 226
Disinfectants, standardisation of, 765
Disinfection, 741
by chemicals, 749
heat, 741
law relating to, 768
of clothes and bedding, 761
excreta, 761
rooms, 762
ships, 763
stations, 767
Disposal of dead, 527
sewage, 504
Distomum crassum, 584
hepaticum, 584
heterophyes, 585
lanceolatum, 584
Ringeri, 585
sinense, 584
Distribution of water, 48
Dochmius duodenalis, 601
Dowson gas, 149
Dracunculus medinensis, 598

Drainage of houses, 497
law relating to, 520, 878
Drains, definition of, 22, 498
examination of, 497
Dry closets, 482
Drying of wines, 350
Dust in air, 140
Dwellings, construction of, 423
law relating to unhealthy, 467
Dysentery, 665
prevention of, 668
Dyspepsia and water, 62

Earth-closets, 482
Echinococcus hominis, 589
Effects of air of factories, 157
vitiated by respiration, 163
Effluents, characters of good, 519
Effluvia from brickfields, 160
offensive trades, 160
sewers and drains, 161
Eggs, 271
Elastic force of vapour, 856
Electrical condition of air, 851
Electrolysis of sewage, 507
Emergency rations, 331
Employment of children, 36
young persons, 36
Encampments, 917
Energy from food, 234
Enteric fever, 59, 278, 669
bacillus of, in water, 116
Ephestia elutella, 307
Equifex disinfecting stove, 745
Equipment of soldiers, 906
Erbswurst, 330
Ergot, 315
Error, probable, 829
Erysipelas, 677
Examination of air, 165
beer, 344
bread, 310
coffee, 363
flour, 308
lime-juice, 368
meat, 256
milk, 281
starches, 324
tea, 362
ventilation, 219
vinegar, 369
water, 74
wine, 351
Excreta, disposal of, 504
removal of, 481, 487
law relating to, 520, 524
Exercise, 379
Expectation of life, 803
Extraction, ventilation by, 188

Factories, air of, 563
law relating to, 560
Factors, table of, for calculating weights, 976
Fans for ventilation, 191
Fasciola hepatica, 584
Fats, 230, 240
in milk, 283
Feathers, 373
Fell-mongering, 538
Filaria Bancrofti, 596
demarquayi, 598
Filaria—*continued.*
immitis, 598
loa, 598
medinensis, 598
ozzardi, 598
sanguinis hominis, 594
Filters, domestic, 69
for field service, 924
sand and gravel, 66
Filtration of sewage, 505, 508
water, 66
Fireplaces, 206
Fish, 268
Flats as residences, 431
Flax, 375
Fleas, 612
Floors, 427
Floor-space in barracks, 889
Flour, 305
Flush-tanks, 493
Food, 223
adulteration law relating to, 336
amount required, 240
concentrated, 327
cooking of, 246
diseases connected with, 249
nutritive value of, 229, 233
of the sailor, 967
soldier, 900
preserved, 327
unsound, law relating to, 336
Foot and mouth disease, 254, 678
Forbes water steriliser, 71, 928
Forces concerned in ventilation, 199
Formalin as a disinfectant, 751
in milk, 291
Formaldehyde, 754
Frequency curves, 812
Fresh air, 181
Friction in ventilation, 203
Frying of food, 249
Fungi in water, 101
Furs, 373

Galton's grate, 208
Gas, coal, 146
effects of combustion on air, 147
stoves, 210
Gelatin as a food, 225
culture medium, 979
Geological origin of soils, 386
Gerber's process of fat extraction, 283
Gin, 354
Glaisher's factors, 855
Glanders, 679
Glossina morsitans, 626
palpalis, 626
Glue-making, 540
Goat's flesh, 259
milk, 272
Goitre in relation to soil, 415
water, 62
Graham's law, 138
Grates, 206
Graveyards, water from, 55
Grease traps, 497
Griess' test for nitrates, 91
Griffith water steriliser, 71, 929
Guinea-worm, 598
Gut-cleaning, 536

HABITATIONS, 421
Hæmaphysalis leachi, 608
Hæmatopota, 621
Hailstorms, 852
Hardness of water, 65, 84
Heat as a disinfectant, 741
    ventilating agent, 188
  effects on health, 832
    milk, 273, 279
Heating by open fires, 206
    stoves, 209
    water, 215
Heights, barometric measurement of, 867
Hemp, 376
Hermite process for sewage, 508
Hippoboscidæ, 628
Hirudinea, 604
Homalomyia canicularis, 623
Home work, law relating to, 565
Hominy, 317
Honey, 325
Horses, air required by, 182
    water required by, 40
Horse-flesh, law as to sale of, 266
Horse-hair, manufacture of, 544
Hospitals, 421, 441
    in army, 896
      navy, 958
    on ships, 958
    infectious, 448
Hot-water supplies, 429
House drainage, 492
    law relating to, 520
Humanised milk, 274
Humidity of air, 135, 853
Huts, 893
Hyalomma hebræum, 607
Hydraulic mean depth, 501
Hydrocarbons, 230
Hydrochloric acid, effects of vapour from, 159
Hydrogen sulphide in air, 173
Hydrophobia, 680
Hygrometers, 854
Hyphomycetes, 569

ICE, 43
Igneous rocks, 387
Illuminants, comparison of, 148
Ilosvay's test for nitrites, 92
Immunity, 633
Impurities in air, 139
    water, 53
Incubation periods, 632
India-rubber, 376, 541
Indicators, 82
Industrial gases, effects of, 142, 157
Infantile mortality, 788
Infantry equipment, 908
Infection, 631
Infectious diseases, 630
    hospitals, 448, 452
      law relating to, 477, 735, 879
Infection and milk, 277, 879
    schools, 438, 887
  notification of, 736
Inferences from water analysis, 125
Influenza, 683
Infusoria in water, 101
Inlets for fresh air, 184, 194
Insects, parasitic, 605

Inspection of animals, 252
    meat, 256
Intermittent filtration of sewage, 505, 510
    supply of water, 50
Invaliding from army, 938
    navy, 973
Iodine as a disinfectant, 760
    purifier of water, 760, 931
Iron in water, 77, 98
  pipes, 51
Irrigation of land by sewage, 505
Isobars, 870
Isolation hospitals, 448
    utility of, 452
    powers of sanitary authority to provide, 477
Isothermals, 849
Izal, 751

JUTE, 376

KALA-AZAR, 685
Kefir, 281
Kerol, 751
Kjeldahl's process, 90
Knackeries, 533
Kola, 365
Koumiss, 281

LACTOSAZONE, 291
Lactose, 273, 285
Lamblia intestinalis, 572
Lathyrus sativus, 320
Latrines in barracks, 894
    on board ship, 954
Lawrence water steriliser, 71, 929
Lead, action of water on, 52
    detection of, in water, 99
    works, sanitary supervision of, 547
Leather as article of clothing, 373
    making, 538
Leeches, 65, 604
Leishmania, 577
Lemon-juice, 367
Lentils, 319
Leprosy, 686
Leptus autumnalis, 605
Liebig's extract of meat, 328
Liernur's sewage system, 502
Life capital, 807
  expectation of, 803
  loss of, at sea, 974
  mean duration of, 809
  probable duration of, 809
  tables, 799
Lights artificial, impurities in air from, 145
Lime juice, 367
  in water, 77
Limnatis nilotica, 604
Linen, 375
Linoleum-making, 541
Lodging-houses, common, 460
    for workmen, 470
Lolium temulentum, 307
London water-supply, 129
Longevity, tests of, 808
Lucilia macellaria, 624
Lysol, 751

MACARONI, 313
Magnesia in water, 77, 84

Maize, 317
Malaria, 687
parasite of, 579
Malta fever, 690
Manihot arrowroot, 322
Manufacture of alkali, 543
horse-hair, 544
manure, 540
Marching, hygiene of, 913
Mares' milk, 272
Margarine, 302, 876
Marine hygiene, 946
Marriage-rates, 776
Means, 810
Mean age at death, 809
duration of life, 809
Measles, 693
Measures of area, 975
Measurement of cubic space, 219
Meat, 252
biscuits, 331
cooking of, 246
diseases arising from, 261
extracts, 328
inspection of, 256
preserved, 333
Mechanical filters, 67
ventilation, 188
Medical Officers of Health, duties of, 11
Melampyrum arvense, 307
Melophagus ovinus, 629
Mercantile marine, hygiene of, 946
Mercurial poisoning, 549
Mercuric chloride as a disinfectant, 749
iodide as a disinfectant, 750
Mercury, use of, in trades, 549
Metallic poisons in water, 65
Meteorology, 842
Meteorological charts, 874
Methods, statistical, 810
Metrical weights and measures, 975
Micro-organisms in air, 173
milk, 287
sewer air, 144
water, 105
Middens, 481
Midwives, control of, 35
Miescher's tubes, 581
Military hygiene, 883
Milk, 272
adulteration of, 289
condensed, 280
epidemics, 278
examination of, 281
law relating to sale of, 293
preservation of, 279
preservatives in, 291
Millet, 318
Mines, air of, 143
Monosaccharids, 226
Montgolfier's formula, 202
Mortality, causes of, 790
in army, 939
mercantile marine, 974
navy, 973
infantile, 788
rates, 791
urban and rural, 786
Mortuaries, law as to, 527
Mosquitoes, 615
Movable dwellings, 477
Movement of air, causes of, 137, 199
determination of, 220
Mumps, 697
Mushrooms, 327
Mustard, 369
Myrbane, effects of, 159

NATURAL ventilation, 193
Naval hygiene, 946
Nematodes, 592
Nessler's re-agent, 87
Nitrates in water, 93
Nitrites in water, 90
Nitro-benzol, effects of, 159
Nitrogen, elimination of, 238
in food, 238
Normal standard solutions, 81
Notification of infectious diseases, 737
Nuisances, inspectors of, 16
law relating to, 27
Nutritive value of food-stuffs, 233
Nyctotherus faba, 582

OATS, 316
Occupation and mortality, 796
Ochromyia anthropophaga, 627
Œstridæ, 627
Offensive gases from trades, 160
trades, 532
law as to, 552, 879
Oïdium albicans, 569
lactis, 570
Oil-lamps, air vitiation by, 148, 182
Oil-stoves, 214
Oleo-margarine, 302
Organic matter in air, 135, 152
water, 86, 90
Ornithodoros moubata, 609
Osazones, 291
Outlets for foul air, 186, 194
Oxygen in air, 133
estimation of, 166
Oxyuris vermicularis, 603
Ozone, 852
sterilisation of water by, 73

PAIL-CLOSETS, 482
Paper-making, 542
Parasites, 568
Parish Councils, sanitary powers of, 2
Parks and open spaces, 31
Peas, 319
Pease sausage, 330
Pediculus capitis, 611
Pellagra, 317
Pemmican, 329
Pentastomidæ, 610
Pepper, 369
Permanganate of potash, 72, 751
Phenol-sulphuric acid method, 93
Phosphates in water, 77
Phosphorus, use of in trades, 156, 550
Phthirius inguinalis, 611
Phthisis among miners, 155
in relation to meat, 263
milk, 277
soil, 417
Physical examination of water, 76
Pipes for water, 50
Piroplasma, 580

Plague, 695, 880
Plasmodium malariæ, 579
Plate cultures from water, 105
Platyhelminthes, 583
Penumatic methods for sewage, 502
Pneumonia, 701
Poisoning from fish, 270
    meat, 262
Polypeptides, 224
Polysaccharids, 226
Population, age and sex distribution of, 775
    density of, 785
    estimation of, 771
Port sanitary authorities. 6, 12, 880
Potatoes, 320
    as culture media, 980
Potential energy of food, 234
Precipitation of sewage, 506
Preservation of food, 332
    milk, 279
Preserved foods, 327
Prevention of anthrax, 640
    beriberi, 645
    cerebro-spinal fever, 647
    cholera, 652
    diphtheria, 664
    enteric fever, 675
    glanders, 680
    kala-azar, 686
    leprosy, 687
    malaria, 689
    plague, 699
    relapsing fever, 705
    scarlet fever, 710
    sleeping-sickness, 711
    small-pox, 720
    tuberculosis, 727
    yellow fever, 734
Probability, theory of, 828
Probable duration of life, 809
    error, 829
Proof spirit, 354
Propulsion, ventilation by, 191
Protection from infectious diseases, 633
    of infant life, 36
Proteins, 224
Protozoa, 571
Psoro-sperms, 261
Puccinia graminis, 307
Puerperal pyæmia, 703
Pulex cheopsis, 613.
    penetrans, 613
Purification of sewage, 506
    water, 65, 925

QUALITATIVE examination of water, 77, 107
Quantitative examination of water, 79, 105

RADIATION of heat, 205
    solar, 846
    terrestrial, 846
    thermometers, 845
Rainfall, 860
Rain-gauges, 861
Rain water, 41
Rame, 375
Rations, emergency, 330
    of sailors, 967
    soldiers, 900
Reck's disinfector, 747
Recruits, 883
Refuse destructors, 480
    disposal, 479
Regulations, sanitary, 23
Relapsing fever, 704
Removal of excreta, 481, 487
    law relating to, 520
Reservoirs for water, 48
Residential flats, 431
Respiration, air vitiated by, 151
Respiratory impurity, 179
Rest, diet for, 240
Rhabdonema intestinale, 593
Rhipicephalidæ, 607
Rhizopoda in water, 101
Rice, 316
Richmond's rule, 285
Rivers, discharge of sewage into, 128
River water, 46
Roasting of meat, 248
Roburite, effects of, 158
Roofs, 426
Rötheln, 705
Rum, 354
Rye, 314

SACCHARIN, 325
Saccharometers, 285
Safety from fire in factories, 565
Sago, 322
Sailors, food of, 967
    mortality of, 972
Salicylic acid in milk, 292
Salt, 370
    meat, 260
    nutritive value of, 232
Sand filters, 66
Sandstone, water from, 54
Sanguisuga medicinalis, 605
    tagalla, 605
Sanitary accommodation in factories, 565
Sanitary Authorities in England and Wales, 1
    Ireland, 5
    London, 4
    Scotland, 4
  bye-laws, 23
  definitions, 21
  inspectors, 16
  law as to adulteration of food, 336
    alkali works, 555
    baths, 34
    canal boats, 474
    cellar dwellings, 472
    cleansing, 484
    common lodging-houses, 460
    dairies and cowsheds, 293
    disinfection, 768
    drains, 520
    employment of children, 36
    factories, 560
    horse-flesh, 266
    housing of working classes, 464
    infectious diseases, 735
      hospitals, 477
    mortuaries, 528
    movable dwellings, 476
    new buildings, 454, 877
    nuisances, 27
    offensive trades, 552

Sanitary law—*continued.*
as to parks, 31
port sanitation, 6, 880
protection of infant life, 36
sewers, 520
slaughter-houses, 557
tenement-houses, 462
unhealthy areas, 465
unsound food, 337
water-supply, 127
Saprolegnia, 570
Sarcocystis miescheriana, 581
Sarcophagidæ, 627
Sarcopsylla penetrans, 613
Scarlet fever, 706
in relation to milk, 277
Scavenging, 479
law relating to, 484
Schistomum japonicum, 586
Schools, 421
influence of, on health, 438
power to close, 440, 877
Scurvy, 250
Sea, discharge of sewage into, 504
Seasonal incidence of disease, 793
Sediment of water, 101
Septic tanks, 509
Sewage, disposal of, 487, 504
law relating to, 524
purification of, 506
standardisation of, 518
Sewers, 498
air of, 144
calculation of flow through, 501, 978
law relating to, 520, 878
ventilation of, 501
Shell-fish and infection, 270
Sherringham valves, 185
Ships, disinfection of, 763, 964
sanitation of, 946
Shoes, 378
Shone sewage elevators, 503
Sickness rates, 798
in army, 939
mercantile marine, 974
navy, 973
Silk, 374
Siphon traps, 495
Sites, 422
Skewness of curves, 813
Slaughter-houses, 533
law relating to, 557
Sleeping-sickness, 710
Slop-closets, 487
Small-pox, 711
protection from, 714
Smoke, nuisance from, 28
test for drains, 497
Snow-water, 43
Soap-making, 537
Soap, test for hardness, 84
Soil, 386
in relation to anthrax, 404
calculus, 405
cancer, 406
cholera, 406
diarrhœa, 409
diphtheria, 410
enteric fever, 412
goitre, 415
Soil—*continued.*
in relation to phthisis, 417
rheumatism, 419
tetanus, 419
yellow fever, 420
Soil-pipes, 492
Soldiers, barracks of, 885
clothing of, 906
food of, 900
mortality of, 934
sickness among, 939
Solids in water, 82
Solutions, preparation of standard, 81
Sources of water-supply, 40
Special hospitals, 448
Specific heat, 205
Spirillum of cholera in water, 118
Spirits, 352
Spirochæta, 576
Sponges as clarifiers of water, 925
Spring water, 43
Standard deviation, 811
diets, 237
solutions, 81
Standardisation of disinfectants, 765
sewage, 518
Starch, 227, 324
Statistics of the army, 933
mercantile marine, 974
navy, 972
vital, 770
Statistical evidence of health, 799
methods, 810
series, 811
tables, 17, 18
Steam, disinfection by, 743
Stewing of meat, 247
Stomoxys calcitrans, 624
Storage of water, 48
Stoves, 209
Streets, new, law as to, 454, 877
Streptothrix, 570
Sugars, 325
Sulphates in water, 77
Sulphur as a disinfectant, 753
dioxide in air, 159, 172
Sunshine, 849
Suspended matter in air, 141, 173
water, 101

Tables, statistical, 17, 18
Tabanidæ, 619
Tabanus bovinus, 621
Tacca arrowroot, 322
Tænia acanthotrias, 589
cucumerina, 591
echinococcus, 589
flavo punctata, 591
madagascariensis, 591
nana, 591
saginata, 587
solium, 588
Tapioca, 322
Tea, 360
Temperature, influence on health, 832
observation of, 842
yearly changes of, 848
Tenements, law as to, 462
Tents, 898
Tetanus, 720
Thermantidote, 191

Thermometers, 842
Thresh's disinfector, 747
Thunderstorms, 851
Ticks as parasites, 605
Tidy's oxygen process, 95
Tobin's tubes, 185
Trades, offensive, 532
law as to, 552
Traps, 495
Trelat's angle, 432
Trematoda, 583
Treponema pallidum, 577
Tricocephalus dispar, 599
Tricomonas vaginalis, 572
Trichinæ, 256, 600
Tripe-boiling, 535
Trough-closets, 490
Trypanosomes, 573
Tub-closets, 482
Tuberculosis, 722
and milk, 277
prevention of, 727
Tube wells, 45
Typhus fever, 728
Tyrotoxicon, 292

UNHEALTHY areas, 465
dwellings, 467
Unsound food, 337
Upland surface water, 43
Urban and rural mortality, 786
Utilisation of blood factories, 534

VACCINATION, 714
Vapour, elastic force of, 136, 856
weight of, 858
Varnish-making, 542
Vegetables, 326
Velocity of air, how calculated, 202, 221
discharge from sewers, 978
Ventilation, 177
artificial, 188
examination of efficiency of, 219
natural, 193
of sewers, 501
soil-pipes, 493
Vermicelli, 313
Vinegar, 368
Vital statistics, 770
of army, 933
mercantile marine, 974
navy, 973
Vitiation, respiratory, 179
Volumetric analysis, 79
V-shaped depressions, 871

WALLS, 425
War rations, 902
Warming, 206
Washington Lyon's disinfector, 747
Water, 37
action on lead, 52
amount required, 38
analysis of, 74
bacteriological examination of, 103
barometers, 865
closets, 490
collection of samples of, 75, 103
constant supply of, 51
diseases from impure, 58
distribution of, 50
examination of, 74
filtration of, 66, 924
impurities in, 53
intermittent supply of, 50
law relating to supply of, 127
purification of, 65, 923
sources of, 40
sterilisation of, 70, 924
storage of, 48
Water-gas, 149
Waterhouse-Forbes steriliser, 71, 928
Watersheds, 42
Weather forecasting, 874
Weevil in flour, 307
Weights of soldiers' kit, 908
Wells, 43
Werner-Schmidt process, 284
Wheat, 304
adulteration of, 307
Whiskey, 353
Whooping-cough, 730
Wind, 200, 849
Wines, 347
Winkler's process, 97
Wool, 371
Wool-sorting, 545
Work, diets for degrees of, 241
estimation of amount done, 384
Working classes, law as to housing of, 464, 470
Workshops, law as to, 560

YEAST extracts, 329
Yellow fever, 732
prevention of, 734
regulations as to, 7, 880

ZINC chloride as a disinfectant, 761
works, hygiene of, 552

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INDEX.

PAGE

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